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NOTES ON PARTURITION IN THE MIDLAND BROWN SNAKE, STORERIA DEKAYI

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The midland brown snake is a small, ovoviviparous natricine snake, which bears its young in late July or August. Brood sizes for Storeria dekayi wrightorum range from 3 to 24 (Wright and Wright, 1957). Broods for Illinois specimens were recorded by Smith (1961) as 5, 6, 12, 17, and 23. Pope (1944) records a brood of 24. Clausen (1936) reports litters of 9 - 20 for S. d. dekayi, and also presents detailed notes on breeding in that subspecies. Inasmuch as detailed observations on birth in wrightorum seem to be lacking, however, I present my observations, to add to the present knowledge of the subspecies.

On 24 July 1971, a large female Storeria dekayi wrightorum, 427 mm. total length, was discovered at the boat dock of the Dawson Lake (McLean) Conservation Area, McLean Co., Illinois. The specimen was coiled beneath a corner of a sheet of black plastic material covering a large wooden post, about 5 feet from the edge of the lake. The snake was caged with a male S. d. wrightorum.

On 29 July, the female was seen moving about the cage. Earthworms (Lumbricus) were offered, and although it attempted to eat, the snake was apparently unable to do so.

20 young were born in the morning of 31 July. The exact time of deposition for 18 snakes was recorded (Table I). During expulsion, the female elevated her tail. When parturition was completed, strong muscular contractions forced another baby towards the vent. Each snake was encased in a membranous sack. Expulsion took from ½ to 1½ minutes; the snakes were completely free of their prenatal sacks within 22 minutes.

The snakes yawned as soon as they broke free of the membranes. Shedding took place immediately. Although quite active at first, the young soon settled beneath objects in the cage. They appeared gregarious, usually coiling about the adults or gathering in cage cracks. A few began feeding upon eathworm bits. Contrary to Clausen's (1936) observations, all insects were refused.

Each snake was gray with black spots, a yellowish collar, and a gray venter. The interior of the mouth was black or pink. Total lengths for a sample of the litter (n = 9) were 90 - 94 mm., mean 92 mm.

One of the young was kept for observation. On 30 September it shed its skin and assumed a light brown color. Most of the black markings faded to dark brown. The neck band became brownish, and the belly changed to pinkish-brown. By 28 March 1972, this snake no longer had the neck ring. It had grown from 93 to 137 mm. total length.

While expelling young the female would frequently follow pre-

viously born snakes. After parturition of all young was completed, she fed voraciously, and in 2 weeks had ingested 14 annelids; afterwards her appetite curbed considerably. The posterior skin folds due to birth disappeared in those weeks.

TABLE I - Time of Parturition for a Litter of Storeria dekayi

Snake	Expulsion Began	Expulsion Completed
1	Time not recorded	Time not recorded
2	" " "	" " "
3	9:35	9:36.5
4	9:45	9:46
5	9:52	9:53.5
6	9:59.5	10:00.5
7	10:05	10:05.5
8	10:13	10:14.5
9	10:17	10:17.5
10	10:20	10:20.5
11	10:28.5	10:29
12	10:30.5	10:31
13	10:31.5	10:32
14	10:36	10:36.5
15	10:40	10:41
16	10:44.5	10:45
17	10:49.5	10:50
18	10:55	10:55.5
19	11:06	11:06.5
20	11:26	11:26.5

I am indebted to Dr. Philip W. Smith and Harlan D. Walley for reading the manuscript and offering suggestions. Dr. Smith aslo allowed me to use his reprint file. I am also grateful to Robert Krapf and Joseph and Rebecca Morris for reading the manuscript. The last two people showed considerable interest in this study and helped in caring for the animals.

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AN IRRUPTION OF LEAST SHREWS, CRYPTOTIS PARVA, IN ILLINOIS

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Abstract:--Thirty-nine least shrews were trapped on a two acre plot in Pope County, Illinois. The population density was estimated to be 35± 18.8 (2SE). Four other species, 21 individuals, were taken from the plot.

The least shrew, Cryptotis parva, is commonly trapped in the eastern United States but in relatively low numbers compared to other small mammals. This is a report of an irruption of the least shrews in Pope County and of some characteristics of the population.

The field in which the shrews were collected (SW ¼, Sec 26, T12S, R5E) was seeded to wheat and alta fescue in the fall of 1963. Alfalfa, redclover, ladino and lespedeza were broadcast over the field the following spring. After the wheat was harvested in 1964 a three-strand barbed wire fence was placed around a two-acre (200 x 450 feet) tract in the field for a study of the interrelationships of leptospirosis in small mammals and cattle. Vegetation within the enclosure was not disturbed, but the remainder of the field was pastured each year by cattle. By 1967 vegetation in the enclosure was a dense growth of fescue with three years accumulated litter forming a heavy ground cover. Annual weeds were common and small patches of blackberry were scattered over the plot.

The enclosure was trapped for 3295 trap-nights from 1964 through 1967 (Table 1). Least shrews dominated the 1967 captures although they were not trapped during the first three years. Comparisons of species densities cannot be made due to differences in trapping effort and in seasons trapped. The total number of least shrews trapped in 1967 and their absence in earlier years was, in part, a reflection of these variations. Trapping success for other species was low in 1967, but shrew captures were not dependent on removal of other species; six least shrews were the only mammals captured during the first four nights of live trapping.

Table 1. Small mammals trapped in a two-acre fenced enclosure in a pasture in Pope County, Illinois

Trapping Period	Trap Nights	Mus musculus	Microtus ochrogaster	Peromyscus maniculatus	Peromyscus leucopus	Cryptotis parva
1964-Aug	760[1]	4	1	-	-	-
1965-Apr	200[1]	1	13	4	-	-
-Jun	160[1]	3	0	7	3	-
-Sep	200[2]	8	0	14	5	-
1966-Jan	200[2]	22	18	19	2	-
1967-Aug	800[1] + 975[2]	8	7	5	1	39

[1]Live traps

[2]Snap traps

During the live trapping in 1967 10 shrews were toeclipped and released and nine others died in the traps. Subsequently, during the removal trapping, 8 marked and 20 unmarked shrews were trapped. The population density, estimated by the Lincoln Index, was 35 $\pm$ 18.8 (2SE) least shrews for the two acre tract. Other than an estimate of 40 least shrews per 14.6 acres (Howell, 1954), least shrew populations have been measured relative to other species collected. Such estimates generally indicate the shrews to be relatively scarce (Hamilton 1944). Food habits studies of barn owls (Davis 1940) and rough-legged hawks (Cope 1949) suggest that these shrews may be more abundant than trapping data indicate. My data indicate that when environmental factors are suitable, least shrews will be abundant and that trapping will reflect their abundance.

Twenty-one of the shrews were males, 16 were females and 2 were partly eaten and could not be sexed. Fifteen of the males and thirteen of the females were considered adults on the basis of size and sexual maturity. There was evidence of reproductive activity in 10 of the 13 adult females; 3 were lactating, 6 were gravid and 1 was gravid and lactating. Embryo counts in the gravid females ranged from 1 to 7 and averaged 4.9.

There was no apparent relationship between the distribution of shrews and the other species trapped. Shrew captures, however, were not uniform over the enclosure but were concentrated at each end of the enclosure supporting reports of intraspecies tolerance in least shrews (McCarley 1959). My data on ranges and movements of least shrews were limited, although 11 shrews were trapped at two or more points: one immature male moved 125 feet, six adult males moved an average of 158 feet with a maximum of 335 feet, four adult females moved an average of 78 feet with a maximum of 100 feet.

This study is a contribution from the Department of Zoology, Eastern Illinois University, Charleston and a grant from the U. S. Public Health Service (CC-00070) to the College of Veterinary Medicine, University of Illinois, Urbana.

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INTESTINAL HELMINTHS OF THE STRIPED SKUNK, MEPHITIS MEPHITIS (Schreber), IN SOUTHERN ILLINOIS

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ABSTRACT -- Fifty-seven striped skunks, Mephitis mephitis, from southern Illinois were examined for intestinal helminths. Infected skunks harbored one or more of the following species: Alaria taxideae, Mesocestoides corti, Oschmarenia (Morosovella) mephitis, Ascaris columnaris, Placoconus lotoris, Physaloptera maxillaris, and Macracanthorhynchus ingens. Alaria taxideae constitutes a new distribution record.

The omnivorous feeding habits of striped skunks, Mephitis mephitis, coupled with their insectivorous and carnivorous tendencies (Lantz, 1923; Dixon, 1925; Hamilton, 1936; Selko, 1937; Llewellyn and Uhler, 1952; and Verts, 1967) expose them to a wide variety of parasites. The importance of these hosts in the epizooteology of diseases of wildlife species as well as certain zoonoses, especially rabies and leptospirosis, has resulted in an increasing recent interest in their parasites not only by parasitologists and wildlife personnel, but also by veterinarians and physicians.

The first extensive review of the literature on the parasites of North American carnivores was published by Stiles and Baker (1935) and includes a list of the helminths reported from mustelids. Erickson (1946) provided lists of the hosts of, and a key to,the North American species of helminths of mustelids and reported on the incidence of these helminths in Minnesota. Subsequent continuing checklists of the helminths of M. mephitis in North America included the reports of Verts (1967) and Dyer (1969).

Although the biology and habitats of striped skunks have been studied extensively in Illinois, little information on their parasitic fauna is available. Levine et al. (1962) reported Skrjabingylus chitwoodorum in the sulci and fissures beneath the dura mater in 2 of 184 M. mephitis examined from northern Illinois. Parasitism of the central nervous system may be a possible explanation for skunks found free of rabies despite their reported antemortem behavior suggesting it (Ewing and Hibbs, 1966; Lynd and Short, 1952). To our knowledge, the only report of intestinal parasites of striped skunks in Illinois is that given by Verts (1967) who examined a total of 153 hosts collected between 1960 and 1962 from northwestern Illinois and listed the intestinal helminths found in 29 skunks. Inasmuch as the parasitic fauna of M. mephitis has not been reported from southern Illinois, the present investigation was undertaken to determine the incidence of intestinal helminths in hosts from this area.

MATERIALS AND METHODS

As a result of a survey of the occurrence of rabies, 57 striped skunks, collected from several ecologically similar counties (Jackson, Jefferson, Perry, Union, and Washington) in southern Illinois between 1958 and 1960 by personnel of the Cooperative Wildlife Research Laboratory of Southern Illinois University at Carbondale, were examined for intestinal helminths. The majority of hosts were trapped; a few were road-killed. As the primary purpose for collecting intestinal tracts of these hosts involved studies of their food habits, the parasites were fixed in either 10% neutral formalin or 70% ethanol. Trematodes and cestodes were stained with either Ehrlich's hematoxylin or Mayer's acid carmulum, destained, dehydrated and gradually cleared by successive treatment for several hours in 25, 50, 75 and then 100% beechwood creosote. Fast green in 95% ethanol was sometimes used to counterstain various structures. Nematodes were cleared in glycerine and studied in temporary mounts. The anterior ends of some specimens were removed and mounted in glycerine-jelly for *en face* studies. Acanthocephalans were pricked by means of fine pins to permit passage of staining fluids and prevent opacity. They were then stained with Mayer's acid carmulum and processed by the methods mentioned above for trematodes and cestodes.

RESULTS AND DISCUSSION

TABLE 1. Intestinal helminths recovered from 57 striped skunks in southern Illinois

Species of helminth	Location in host	No. animals infected	Per cent infected
TREMATODES			
Alaria taxideae	Small intestine	2	3.5
CESTODES			
Mesocestoides corti	Small intestine	7	12.3
Oschmarenia (*Morosovella*) *mephitis*	Small intestine	2	3.5
NEMATODES			
Ascaris columnaris	Small intestine	21	36.8
Placoconus lotoris	Small intestine	6	10.5
Physaloptera maxillaris	Stomach	55	96.4
ACANTHOCEPHALANS			
Macracanthorhynchus ingens	Small intestine	3	5.3

Seven species of helminths were recovered. These included one trematode, two cestodes, three nematodes, and one acanthocephalan (Table 1). Fifty-six skunks were infected with one or more species of helminths; 45 were infected with nematodes, 6 with nematodes and tapeworms, 3 with nematodes and acanthocephalans, and 2 with nematodes, tapeworms and flukes.

Trematodes

Alaria taxideae Swanson and Erickson, 1946

This species was the only fluke encountered. It occurred as a mixed infection with Ascaris columnaris and Mesocestoides corti in one host and with A. columnaris, Placoconus lotoris and M. corti in the second host. Infection of A. taxideae were light in both hosts; the average number of flukes per host was 4.3.

Our report of A. taxideae is apparently the sixth known occurrence of this trematode in M. mephitis and its occurrence in Illinois constitutes a new distribution record. This parasite has previously been reported from striped skunks in Minnesota (Swanson and Erickson, 1946; Erickson, 1946), Maryland (Goldberg, 1954), Michigan (Chandler, 1954), Louisiana (Babero, 1960), and North Dakota (Dyer, 1970). This species has a wide host distribution in mustelids and is known to occur in Spilogale putorius, Mustella erminea, M. frenata and Taxidea taxus in Minnesota (Swanson and Erickson, 1946; Erickson, 1946) and T. taxus in North Dakota (Leiby, Sitzmann, and Kritsky, 1971).

The life history of A. taxideae is unknown, but possibly it is the same as for other species of Alaria. Pearson (1956) reviewed the literature on several species of Alaria whose life cycles have been ascertained. Essentially they involve 1) a snail first intermediate host, 2) a vertebrate second intermediate host that harbors the mesocercariae, 3) a collector or paratenic host, that makes the mesocercariae more readily available to the definitive host because of its habitat and food habits, and 4) the definitive host in which the diplostomulae and adults develop.

Cestodes

Mesocestoides corti Hoeppli, 1925 (= M. variabilis Mueller, 1928; M. manteri Chandler, 1942)

This tapeworm always occurred as a mixed infection. It was found with Ascaris columnaris in 4 hosts, A. columnaris and Placoconus lotoris in 2 hosts, and A. columnaris, P. lotoris and Alaria taxideae in 1 host. This cestode has been reported from Mephitis mephitis in California (Mueller, 1928; Voge, 1953, 1955b; Mead, 1963), Minnesota (Erickson, 1946), Wisconsin (Rausch and Tiner, 1949), Louisiana (Babero, 1960), northwestern Illinois

(Verts, 1967), North Dakota (Dyer, 1970) and from several other mammalian hosts including Canis latrans, Lynx rufus, Martis pennanti, Mephitis macroura, Mus musculus, Procyon lotor, Spilogale gracilis, S. putorius, Urocyon cinereoargenteus, U. litteralis, and Vulpes macrotis.

The present taxonomic criteria for differentiating species of the genus Mesocestoides are inadequate. Morphological differentiation is slight and variability of characters extensive. In a study of this genus, Voge (1955a) concluded that on the basis of available date M. corti and M. variabilis cannot be satisfactorily differentiated and that M. manteri is a dwarf form of M. variabilis. For these reasons, she proposed that M. manteri and M. variabilis be regarded as synonyms of M. corti.

The complete life history of Mesocestoides is not known. A survey of the literature reveals numerous reports of tetrathyridia, the stage infective to carnivores, in the liver, mesenteries, cardiac muscle and body cavity of various amphibians, reptiles, and mammals (Voge, 1953; Specht and Voge, 1965; Grundmann, 1956; James and Ulmer, 1967). In this report, infected skunks presumably acquired M. corti by ingesting vertebrates infected with tetrathyridia. Of the various carnivores examined in this laboratory, M. mephitis appears to be the important definitive host in southern Illinois.

Oschmarenia (Morosovella) mephitis (Skinker, 1935) Spassky, 1951 (= Oochoristica mephitis Skinker, 1935)

This species occurred as a mixed infection with Ascaris columnaris in one host and with A. columnaris and Placoconus lotoris in the second host. This parasite has been reported from striped skunks in Georgia (Skinker, 1935), Illinois (Leigh, 1940; Verts, 1967), Massachusetts (Self and McKnight, 1950), Florida (Loftin, 1961) and North Dakota (Dyer, 1970). Rankin (1946) also found this parasite in Urocyon cinereoargenteus. This life history of this tapeworm is not completely known. The larvae probably develop in beetles.

Nematodes

Ascaris columnaris Leidy, 1856

This nematode was found as a single infection in 11 hosts and as a mixed infection with Mesocestoides corti in 3 hosts, M. corti and Alaria taxideae in 1 host, Placoconus lotoris in 2 hosts, P. lotoris and M. corti in 2 hosts, P. lotoris, M. corti and A. taxideae in 1 host and P. lotoris and Macracanthorhynchus ingens in 1 host. This parasite has been reported from M. mephitis in Quebec (Choquette, 1951; Webster and Wolfgang, 1956), Maryland (Dikmans and Goldberg, 1949), Louisiana (Babero, 1960), California (Mead, 1963), northwestern Illinois (Verts, 1967) and North Dakota (Dyer, 1970). Early stages in the life cycle of this species reside in the lungs of the host.

Physaloptera maxillaris Molin, 1860

This species was the most common nematode collected. Marked hypertrophy of the stomach wall was observed in heavy infestations. This nematode has been reported from M. mephitis in Quebec (Choquette, 1951; Webster and Wolfgang, 1956; Webster and Beauregard, 1965), Maryland (Dikmans and Goldberg, 1949; Goldberg, 1954), Louisiana (Babero, 1960), California (Mead, 1963), northwestern Illinois (Verts, 1967) and North Dakota (Dyer, 1970). It has also been reported in other Mustelidae from North America. Insects probably are the intermediate hosts of this parasite.

Placoconus lotoris (Schwartz, 1925) Webster, 1956 (= Uncinaria lotoris Schwartz, 1925; Arthrocephalus lotoris (Schwartz, 1925) Chandler, 1942).

This hookworm occurred as a single infection in 2 skunks and as a mixed infection with Ascaris columnaris in 1 host, A. columnaris and Mesocestoides corti in 2 hosts, and A. columnaris, M. corti and Alaria taxideae in 1 host. Infections were light in all hosts; the average number per hosts was 5.2. This nematode has been reported in M. mephitis from Maryland (Dikmans and Goldberg, 1949), Quebec (Choquette, 1951; Webster and Wolfgang, 1956), Louisiana (Babero, 1960) and northwestern Illinois (Verts, 1967).

The first report of a hookworm with buccal capsule formed of articulating plates was that of Ortlepp (1925) who established Arthrocephalus with A. gambiensis from an African mongoose as type. Subsequently, Schwartz (1925) described Uncinaria lotoris, a hookworm with an articulated buccal capsule from a North American racoon, Procyon lotor. Chandler (1942) transferred this species to Arthrocephalus. Later, Webster (1956) pointed out that in A. gambiensis there is a dorsal cone but no teeth, while in A. lotoris the dorsal cone is absent and ventral teeth are present. On the basis of these differences, Webster transferred A. lotoris to a new genus Placoconus.

Acanthocephalans

Macracanthorhynchus ingens (Linstow, 1879)

This parasite occurred as a single infection in 2 hosts and as a mixed infection with Ascaris columnaris in 1 host. This acanthocephalan has been reported in M. mephitis from Maryland (Goldberg, 1954), Louisiana (Babero, 1960) and northwestern Illinois (Verts, 1967). It has also been reported from other Mustelidae in North America. The life cycle for M. ingens was worked out experimentally by Moore (1946). Development occurred in grubs of Phyllophaga crinita, P. hirtiventris, Ligyrus sp. and in Rana pipiens.

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MICROSPORIDA OF THE GENUS PARATHELOHANIA OCCURRING IN THREE SYMPATRIC SPECIES OF MOSQUITOES, CULISETA INORNATA, CULEX PIPIENS AND CULEX TERRITANS IN SOUTHERN ILLINOIS

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ABSTRACT — Microsporida of the genus Parathelohania were found in the adipose tissue and haemocoels of three sympatric species of larval mosquitoes, Culiseta inornata, Culex pipiens and C.territans, from southern Illinois. Because the number of characters for separation of species were few and the intraspecific variation was extensive, accurate identification was extremely difficult. Comparison of mean spore size was considered the most reliable character. Microsporida from all three hosts resembled P.opacita morphologically and showed no significant statistical difference in spore size. Specimens from all three hosts were identified as P.opacita. New host records were established for Culiseta inornata and Culex pipiens. A new locality record was established for P.opacita infecting C.territans.

INTRODUCTION

Microsporidan parasites have been reported from each of the mosquitoes Culiseta inornata, Culex pipiens and C.territans of North America. Parathelohania inimica was described from Culiseta inornata from California by Kellen (1962) and later reported from the same host in Louisiana (Chapman, 1966). Culex pipiens has been reported as the host of Stempellia magna in Illinois (Kudo, 1920). Parathelohania opacita has been reported from Culex territans in Louisiana (Chapman, 1966), New York and Alabama (Kudo, 1924) and Connecticut (Anderson, 1968). Culex territans was also found parasitized by S.magna in Pennsylvania (Kudo, 1921), Pleistophora chapmani in Louisiana (Clark, 1971) and Pleistophora sp. in Louisiana (Chapman, 1966).

Microsporidans are difficult to identify positively as there are few known taxonomic characters. Thompson (1960) clarified much identification by demonstrating the invariability of spore size of a microsporidan species in several host species. This character depends upon accurate measurement of spore size and calculation of means in a set way. Useful comparison cannot be made between a set of extremes given by the author of the species and the mean and standard error of subsequent investigators. Inasmuch as comparison for identification must be made from the author's measurements or type material, positive identification depends upon the amount of variation the later worker considers acceptable.

MATERIALS AND METHODS

During May, 1972, mosquito larvae were collected from a pond-overflow area on the Southern Illinois University campus at Carbondale, Illinois. In the laboratory the mosquito larvae were placed in white enamel trays and observed for infections. Larvae appearing abnormal in shape, color or behavior were identified by utilizing the keys of Ross (1965), smeared on microscope slides, air dried, fixed in absolute methanol for 1 minute and stained in a 1:3 solution of Giemsa's stain and buffer solution for 5 minutes.

All spores were examined under a compound light microscope (1000X), and forty spores were measured from each of the stained smears with the aid of an ocular micrometer. The analysis of variance technique at the 0.01 level of significance was applied to the measurements for statistical comparison.

RESULTS

A total of ten fourth instar larvae and one pupa of Culiseta inornata, one fourth instar larva of Culex pipiens and one fourth instar larva of C.territans were found to be infected with a species of Parathelohania. All infected hosts came from the same temporary pool, a tire track about 8 inches deep, in the overflow area.

Table 1 shows the measurements of the stained spores, and the measurements of stained P.opacita of Anderson (1968). All the spores were similar in morphology, except for a few in each population without a truncated end. All are in the general size range of P.opacita, and the extremes of each population of spores are nearly the same; they approximate the 5.5—4.5 x 4.0—3.3 μm extremes described by Kudo (1924) in C.territans. There was no statistically significant difference between the means of the spores in the four representative Culiseta inornata populations (Table 1), the Culex territans population and the C.pipiens population. These spores are all similar in morphology to those microsporidan spores identified as P.opacita by Weiser which were made available by the Department of Pathobiology of the University of California, Irvine.

An all cases the infection occurred in the adipose tissue and had filled the haemocoel with spores and pansporoblasts. The spores poured out when the body cavity was opened.

The Parathelohania collected from the three species of mosquitoes is P.opacita. This identification is based on spore size and shape. These findings establish new host records for P.opacita in Culiseta inornata and Culex pipiens. A new locality record is established for P.opacita infecting C.territans.

DISCUSSION

The experiments of Thompson (1960) suggest very little variation in spore size between host species. The data of Bailey (1967) show a continuation of mean spore sizes in populations of P. inimica (s.str.) and P. inimica canadensis between two statistically different extremes by placement of samples in an order in which adjacent spore measurements were not found to be significantly different (using the "t" test to compare adjacent pairs). The analysis of variance technique used in this study is a more robust test than the "t" test and at the stringent 0.01 level of significance accounts for both biological and artificial variation among the spores in a population. There may be a relatively large amount of variation within species of Parathelohania and little host specificity, as shown by Hazard (1968) in a redescription of P. legeri. The correlation between statistical variation and biological variation is not clear. The identity of many species of Parathelohania will be doubtful until a redescription of P. opacita is made and more biological data accumulated, particularly by an oral infection technique for Parathelohania.

TABLE 1. — Measurements of Fixed Spores of Parathelohania opacita. n = 40

Host	Length µm		Width µm	
	Extremes	Mean	Extremes	Mean
Ca. inornata (Illinois)	6.0-4.4	5.02±0.06 [1]	4.2-3.0	3.90±0.04
Ca. inornata (Illinois)	6.0-4.0	5.00±0.07	4.4-2.8	3.80±0.07
Ca. inornata (Illinois)	6.1-4.0	4.90±0.08	4.4-3.0	3.70±0.08
Ca. inornata (Illinois)	6.0-4.0	5.04±0.05	4.4-3.0	3.80±0.05
C. territans (Illinois)	5.4-4.2	4.90±0.06	4.2-3.0	3.80±0.04
C. pipiens (Illinois)	6.0-4.0	5.20±0.06	4.8-3.0	3.80±0.06
C. territans [2] (Connecticut Anderson, 1968)	—	5.30±0.13	—	4.10±0.06

[1] Standard error of the mean

[2] n = 100

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EFFECT OF LOW WATER POTENTIAL ON THE ACTIVITY OF MITOCHONDRIAL, CHLOROPLAST AND SUPERNATANT MALIC DEHYDROGENASE FROM THE HALOPHYTE, SALICORNIA PACIFICA.

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ABSTRACT. Salicornia spp. are among the most salt tolerant of higher plants with tissue water potentials (ψ) falling to -80 bars. The effect of low ψ on in vitro malic dehydrogenase (MDH) isozyme activity from young (low-salt) and old (high-salt) tissue was examined. Sucrose and NaCl (0.5, 0.75, and 1.0 M) were employed as assay osmotica. Activities of MDH isozymes were found to decrease (60%) but relative proportions of each fraction remained constant with increasing internal salt. A retardation of substrate penetration into intact mitochondria and a concomitant parallel inhibition of solubilized enzyme were observed with decreasing ψ (50% in 0.5 M NaCl or 1.0 M sucrose). Sucrose was more inhibitory than NaCl. Supernatant was more tolerant of low ψ than mitochondrial MDH. Activity of MDH in 1 M NaCl could be restored to 80% of the control with increased (nine-fold) substrate. These data indicate subcellular enzymatic integrity in this halophile at low water potential (-20.7 bars) and possible adaptation through increased in vivo substrate levels.

The great majority of plants are glycophytes or plants adapted to relatively low levels of salinity. Growth of glycophytes on increasingly saline soil results in progressive stunting and finally death. Numerous studies have been conducted to distinguish between effects due to a lowered water potential (ψ) and those due to the specific solute used to obtain it (Bernstein and Hayward, 1958). Many of the recent studies have attempted to ellucidate the mechanisms of inhibition through analysis of solute effects on enzymatic systems. The results of these studies on glycophytes have provided evidence for at least four possible mechanisms. The first concerns the osmotic component of ψ and its effects on enzymes compartmentalized within organelles. As the mitochondrion is subjected to increasing osmotic stress it contracts and component enzymes are inhibited. This inhibition may be due to decreased accessibility of substrate (Johnson and Lardy, 1958; Atmonson and Davis, 1967) or to concentration of endogenous substrates to the point of inhibition (Flowers and Hanson, 1969). The second entails inhibition of the enzyme per se due to the specific chemical nature of the solute. The third involves the change in tertiary structure of the enzyme due to effects of low water activity on protein hydration (Weimberg, 1967). The fourth possibility involves the suppression of enzyme synthesis as the tissue accumulates salt (Porath and Poljakoff-Mayber, 1964 and 1968).

Another view of the mechanisms of enzymatic response to low water activity might be obtained by utilizing a plant adapted to high salinity (i.e., a halophyte). The data presented in this paper are derived from experimentation utilizing the halophyte Salicornia pacifica. The species of the genus Salicornia are among the most salt tolerant of all higher plants, characteristically accumulating very high tissue salt (NaCl) during the growing season (Chapman, 1960). The perennial nature of S. pacifica enables

one to study young, low-salt tissue concomitantly with older, high-salt tissue.

Malic dehydrogenase was chosen as the enzyme to be studied since it: 1, has representative isozymes both within the organelles and the cytoplasm; 2, has been extensively studied in glycophytes subjected to saline conditions; and 3, can be measured with a high degree of reproducibility.

MATERIALS AND METHODS

Young, green stems and the older, red stems were obtained from Salicornia pacifica collected from the salt marsh adjacent to the marina at Palo Alto, California. The chemical composition of the bay water in which they were growing was given by Gibor (1956). Osmotic values were calculated from freezing point depression values of their expressed sap measured by a Beckman differential thermometer. Protein content of the two types of tissue was determined by means of the method of Lowry, et al. (1951) following its precipitation by perchloric acid (7%).

Mitochondrial, chloroplast, and supernatant (cytoplasmic) malic dehydrogenase (MDH) were isolated from the stems by a modification of the method of Brandon (1967) devised for enzymatic studies on succulent tissues. The procedure consisted of grinding 10 g of freshly harvested stems in 50 ml of a medium that was 0.35 M mannitol, 0.1 M Tris-HCl, 0.01 M cysteine, and 2% (w/v) bovine serum albumen (pH 7.6) in a chilled mortar. The homogenate was squeezed through four layers of cheesecloth and centrifuged at 100 x g for 5 minutes. Chloroplasts were sedimented from the supernatant by centrifugation of 1000 x g for 10 minutes. The supernatant from this step was centrifuged for 30 minutes at 15,000 x g to obtain a mitochondrial fraction. The mitochondrial and chloroplast pellets were each suspended in 5 ml of 0.35 M mannitol. The last supernatant was retained as the source of supernatant MDH.

Malic dehydrogenase was assayed by following the oxidation of NADH at 340 nm in a Zeiss PM QII spectrophotometer. The components of the assay medium were: Tris, 200 μmoles, pH 7.4; $MgCl_2$, 10 μmoles; oxaloacetic acid (freshly prepared and neutralized before use), 2 μmoles; NADH, 0.2 μmoles; malic dehydrogenase fraction, 50 μl; and distilled water or the appropriate solute solution to 3.0 ml total volume. Variations in substrate and solute concentration are presented in the results. Both NaCl and sucrose were employed as assay osmotica. Mitochondria and chloroplasts were solubilized where noted by including 50 μl of Tween-20 in the assay medium.

Results are expressed as units (ΔO.D. of 0.01/min) per g fresh weight.

RESULTS

The osmotic values obtained from the young, low-salt tissue and older, high-salt tissue used throughout the experiments were found to average (three determinations) -5.8 and -20.7 bars, respectively.

Protein content (mg/g fresh weight) was found to average (three determinations) 15.4 and 9.6 for the low- and high-salt tissues, respectively.

Mitochondrial MDH from green, low-salt tissue was found to be stimulated by NaCl in concentrations of up to 0.2 M (Table 1). Above 0.2 M, however,

TABLE 1. MDH Activity of Intact and Solubilized Mitochondria in the Presence of Varying Concentrations of NaCl.

Molarity of NaCl in Assay Medium	Units of MDH from Intact Mitochondria Per Gram Fresh Weight of Tissue	% Inhibition (I) or Stimulation (S) over Control	Units of MDH from Solubilized Mitochondria	% Inhibition (I) or Stimulation (S) over Control
0 (Control)	70	0	250	0
0.2	105	33.3 (S)	345	38 (S)
0.4	70	0	210	15 (I)
1.0	30	57 (I)	85	66 (I)
1.5	30	57 (I)	75	70 (I)

increasing NaCl concentration progressively reduced MDH activity. Solubilization of the MDH brought about approximately a three-fold stimulation of activity in the control and at all concentrations of NaCl up to 1.5 M. Although the MDH activity was always higher following solubilization, the response to increases in NaCl closely paralleled that of the enzyme in the intact mitochondrion.

The salt effect on mitochondrial MDH from low-salt tissue was no different from that of MDH isolated from high-salt tissue (Table 2). The total units of mitochondrial MDH were, however, always about 50% less in the high-salt tissue.

TABLE 2. Effect of Salt on MDH Activity of Intact and Solubilized Mitochondri from Low- and High-Salt Tissue.

Molarity of NaCl in Assay Medium	Units of MDH from Intact Mitochondria Per Gram Fresh Weight of Tissue	% Inhibition	Units of MDH from Solubilized Mitochondria	% Inhibitio
		Green, Low-Salt Tissue		
0.00	75.0	0	300	0
0.75	28.5	62	130	56
		Red, High-Salt Tissue		
0.00	43.0	0	160	0
0.75	17.0	60	75	53

Increasing tissue salt concentration did not affect the relative distribution of the MDH among the subcellular fractions (Table 3). While lower values of MDH ($\sim$50%) were observed in the fractions from high-salt tissue, the relative distribution of MDH was found to be about the same.

TABLE 3. Total Units and Their Distribution in the Various Fractions from Salicornia pacifica of Varying Internal Salt Content.

Fraction	Total Units Per Gram Fresh Weight	Percentage of Total in Homogenate
	Green, Low-Salt Tissue	
Homogenate	1400	100.0
Chloroplast	300	21.0
Mitochondrial	260	18.5
Supernatant	720	53.5
	Red, High-Salt Tissue	
Homogenate	660	100.0
Chloroplast	150	22.0
Mitochondrial	160	24.0
Supernatant	360	54.0

When each of these sources of solubilized isozymes were tested for their response to NaCl, the order of increasing resistance was found to be chloroplast, mitochondrial, and finally supernatant MDH (Table 4). When these sources of MDH were compared on the basis of origin from low- and high-salt tissue, chloroplast and mitochondrial isozymes display no differences in resistance to high assay NaCl (Table 4). However, the supernatant MDH from high-salt tissue appears to be much more inhibited by NaCl than that from low-salt tissue.

To determine whether the effect of high solute concentration on mitochondrial MDH was osmotic or due to the specific nature of the solute, both sucrose and NaCl were used as assay osmotica. In order to evaluate the potential osmotic effect both intact and solubilized mitochondria from low-salt tissue were employed. Sucrose proved to be most inhibitory to MDH within the intact mitochondrion even though 1 M NaCl provides almost twice as many solute particles as 1 M sucrose (Table 5). However, unlike the parallel inhibition of intact and solubilized mitochondrial MDH exerted by NaCl (Table 1), there appears to be a much greater restoration of sucrose-inhibited, mitochondrial MDH by solubilization (Table 5). It is also evident that once solubilized, the MDH is about equally sensitive to the two osmotic agents.

MDH inhibition by high concentrations of its substrate was observed for the mitochondrial isozyme from Salicornia. However, the response of the mitochondrial enzyme from low-salt tissue to increasing substrate concentrations was just the opposite in high concentrations of assay NaCl (Figure 1). In fact, the loss of activity in the MDH of the intact mitochondrion due to the presence of 1 M NaCl could be completely restored by a four-fold increase in substrate.

TABLE 4. Effect of Increasing Amounts of NaCl on Activity of Solubilized and Supernatant MDH from Tissue of Low and High Salt Content.

Fraction	Units Per Gram Fresh Weight	Molarity of NaCl in Assay Medium	% Inhibition
	Green, Low-Salt Tissue		
Chloroplast	300	0.00 (Control)	0
	220	0.50	27
	130	0.75	55
Mitochondrial	300	0.00	0
	160	0.50	45
	130	0.75	56
Supernatant	780	0.00	0
	630	0.50	20
	480	0.75	38
	450	1.00	42
	Red, High-Salt Tissue		
Chloroplast	150	0.00	0
	80	0.50	43
	70	0.75	50
Mitochondrial	160	0.00	0
	100	0.50	34
	70	0.75	53
Supernatant	360	0.00	0
	360	0.50	0
	300	0.75	17
	270	1.00	25

TABLE 5. Effect of the Nature of the Solute on MDH of Intact and Solubilized Mitochondria from Low Salt Tissue.

Solute in Assay Medium	Units of MDH from Intact Mitochondria	% Inhibition	Units of MDH from Solubilized Mitochondria	% Inhibitio
None (Control)	78	0	265	0
NaCl (0.75 M)	32	59	126	51
NaCl (1 M)	30	62	80	70
Sucrose (1 M)	0	100	159	40
Sucrose (1.5 M)	0	100	106	60

DISCUSSION

The MDH isozymes of the halophyte Salicornia pacifica show the rise in activity (in vivo) with increasing salt concentration as has been previously reported (Hiatt and Evans, 1961; Weimberg, 1970). However, important differences in magnitude exist. While the soluble MDH from peas shows maximal activity at 0.02 M NaCl and inhibition to totality at 0.3 M (Weimberg, 1967), that from Salicornia is maximally stimulated at 0.2 M NaCl. Moreover, considerable activity of the Salicornia MDH isozymes may be observed at 1.5 M NaCl. This much greater activity in high NaCl concentration may reflect some structural adaptation in the MDH of Salicornia.

A progressive inhibition of the MDH in the intact mitochondrion due to increasing assay solute concentration was observed. However, the nature of this inhibition is not solely due to an osmotically-induced restriction of substrate penetration as suggested by Atmonson and Davis (1967). There is instead, a parallel decrease in activity under similar solute conditions in the solubilized enzyme. Flowers and Hanson (1969) found a similar response for the MDH of soybean mitochondria. In addition, Atmonson and Davis (1967) found no difference in inhibition exerted by NaCl and sucrose. The MDH of Salicornia whether solubilized or within the mitochondrion, is inhibited to a much greater degree by sucrose. While Flowers and Hanson (1969) observed a difference between sucrose- and KCl-induced inhibition, the KCl was reported to be more inhibitory. The opposite was seen in the present study, where the salt (NaCl) was less inhibitory than sucrose. These findings may indicate an osmotically-induced inhibition due to a non-penetratable sucrose and a more tolerant enzyme to the penetrating NaCl. The similar magnitude of inhibition of the solubilized MDH by sucrose and NaCl indicates that there exists a true inhibitory effect from lowered ψ per se. This may result from an altered hydration as postulated by Flowers and Hanson (1969). It is unlikely that there was inhibition due to increased substrate levels accompanying volume decrease in the osmotically-contracted mitochondrion. The MDH activity suppressed by 1 M NaCl could instead be completely restored by increasing the substrate concentration.

The constancy in distribution of MDH among the subcellular fractions as the tissue rose in internal salt content is probably another manifestation of adaptation in Salicornia (Table 3). The lower activities of MDH in the high-salt tissue are more apparent than real. This results from the expression of activity as units per gram fresh weight. As noted in the Results section, due to increased succulence in the high-salt tissue, the protein values per gram fresh weight declined. Specific activities of the malic dehydrogenases were then not greatly different.

There appeared to be no significant difference in degree of salt inhibition between that exerted on mitochondrial MDH from low- or high-salt tissue. This indicates that there is no change in mitochondrial or MDH enzyme structure as the tissue ages and rises in salt content. The MDH of the supernatant from high-salt tissue does seem to be more salt tolerant to high NaCl concentration in the assay medium (Table 4). The significance of this observation may lie in the fact that this latter isozyme is not compartmentalized and must function in the low water activity that results from increasing tissue salt.

Another mechanism of adaptation to high internal salt may lie in the interpretation of the data in Figure 1. There is little doubt that increasing substrate concentration can bring about greater activity in salt-inhibited MDH. Such increasing substrate concentration would be very inhibitory to the enzyme were it not in the presence of high salt. The hypothetical characteristics of this adaptation would be two-fold. First there must be some shift to high endogenous substrate levels as internal salt increases. Webb and Burley (1965) and Joshi, et al. (1962) have shown that in a facultative

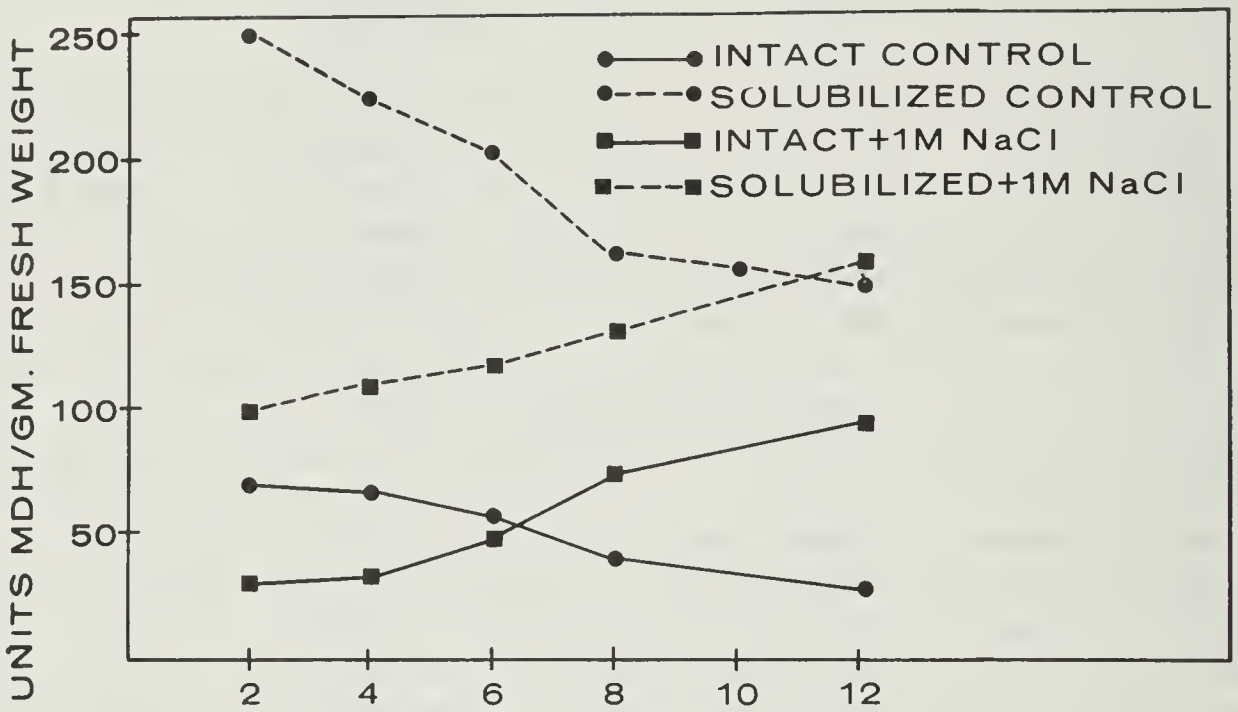

FIGURE 1. EFFECT OF SUBSTRATE CONCENTRATION ON INTACT AND SOLUBILIZED MDH ACTIVITY.

halophyte there is a shift towards the formation of more amino acids and malic acid with increasing salinity. This may reflect some mechanism of increasing substrate levels for salt-sensitive enzymes. Secondly, an overcoming of an effect of high NaCl with increased substrate suggests some type of competitive inhibition exerted by the salt. Weimberg (1967) has provided kinetic evidence that there does exist such a competition between NaCl and oxaloacetic acid for the active site of MDH. The data presented here (Table 5) suggests that this apparent competitive effect might be due to a less available active site resulting from decreased hydration of the enzyme. In this case increasing substrate would increase activity according to the principle of mass action. Of all the possibilities for both the basis of salt inhibition of activity and the mechanism of adaptation to it, this latter hypothesis seems best supported by the data of the present study.

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FLOOD-CAUSED TREE MORTALITY AROUND ILLINOIS RESERVOIRS

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ABSTRACT

The effects of high reservoir levels in Rend Lake and Lake Shelbyville, both located in southern Illinois, on species of the streamside forest are described. Tolerances to growing season inundation for 24 tree species were determined from data on tree elevation and duration of flooding. A limit of 30 days of flooding during spring and summer months is suggested to insure survival of tree vegetation around reservoir margins.

INTRODUCTION

The impoundment of rivers and streams imposes stresses on the streamside forest community which were never experienced under natural conditions. The streamside plant associations develop in response to the complex of environmental factors which sorts out species that are intolerant of the existing conditions. Flood regime is the most determinant of the physical environmental parameters which control the distribution of tree species in the bottomland areas of the streamside forest (Bell, 1974). As water-resource development projects are established, the natural flooding characteristics of rivers are altered and the operation and management of reservoir levels can strongly affect organisms within its influence. Although the species distribution in relation to existing flood regimes can be a good indicator of flood tolerance, the distribution is probably a better indication of the tolerance of seed and young seedlings. Early stages of development are much more susceptible to the detrimental effect of flood conditions than are later stages (Lees, 1964). Protection of reservoir margin and riparian forests requires management plans which are based on the ecological tolerance of mature individual to water levels.

Timber clearing within the normal pool of a reservoir eliminates the problem of dying trees in the reservoir. Peripheral clearing may, however, be only partially completed due to shortages of funds, high water, wildlife preserves, or other reasons. Areas of bottomland timber upstream from the normal pool, but within the area influenced by operation of the dam, experience flood durations, frequencies, and magnitudes different from those under which these communities normally functioned. In areas surrounding the reservoir, upland forest communities which have rarely, if ever, experienced flood conditions may be subjected to environmental stresses resulting from flood water impoundment. Observation of the detrimental effects of high water on trees in previously established reservoirs can be extremely helpful in formulating operational guidelines for proposed or newly constructed impoundments.

The spring and early summer floods of 1973 produced abnormally high water conditions in the Lake Shelbyville and Rend Lake reservoirs in south

central and southern Illinois, respectively. Floods along the Mississippi River system prevented the reservoir managers from employing release rates sufficient to alleviate flooding conditions above the dam. Thus, many uncleared areas above these reservoir dams were inundated for most of the 1973 growing season. The objective of the current study was to determine relationships between tree mortality and the period of inundation to better understand the ecological limits of tree species in the Midwest to flood conditions.

STUDY AREA AND METHODS

Sampling sites were established at three locations each on Rend Lake and Lake Shelbyville. Rend Lake is a multi-purpose project of the Corps of Engineers on the Big Muddy River in Franklin County near Benton, Illinois. Two of the Rend Lake sampling sites were located in Sec. 40 T4S, R3E, 3rd PM (Long. 88°55'W, Lat. 38°09'N), and the third in Sec. 4, T5S, R2E, 3rd PM (Long. 88°59'W, Lat. 38°07'N). Lake Shelbyville is a unit of the general comprehensive plan for the development of the Kaskaskia River Basin for flood control, water supply, fish and wildlife conservation, recreation, and downstream water quality control. It is located on the Kaskaskia River in Shelby and Moultrie counties near Shelbyville, Illinois. The three sampling sites were located within the Kaskaskia Fish and Wildlife Management Area, Sec. 16, T13N, R5E (Long. 88°40'W, Lat. 39°34'N).

Sites were chosen to incorporate both live trees and trees judged to have died within the 1973 growing season. Elevations of selected trees within each sampling site were determined by multiple foresights from a transit location in the center of the sampling site. Trees were chosen to fully represent the species and elevation diversity within the sampling site. Bench marks for the transit site were determined from elevations of the lake level on the sampling day and the season's highest water mark. From the daily lake level records and the elevation of the trees within the sampling sites, it was possible to determine the relationship between the length of the inundation period and tree survival. Nomenclature follows Jones (1963) except that Fraxinus pennsylvanica includes F. lanceolata.

RESULTS

Thirty-two species of trees were identified among the 671 trees sampled at Rend Lake and Lake Shelbyville. Of these, sample numbers for eight species were judged insufficient to determine their tolerance to flood conditions. Data on tree mortality in relation to flood duration are shown in Table 1. Within each flood-duration category, the percentage of flood-killed trees to the total number sampled provides the data to develop linear regression equations and describe the relationship between the length of flood duration and tree mortality.

Inundation of trees for less than 30 days during the growing season of one year was insufficient to kill any established tree. When flood durations reached 50 days, one of three Quercus velutina (Black oak) observed had not survived the flood conditions. Mortality among the predominatly upland species became apparent when flood conditions extended to more than two months.

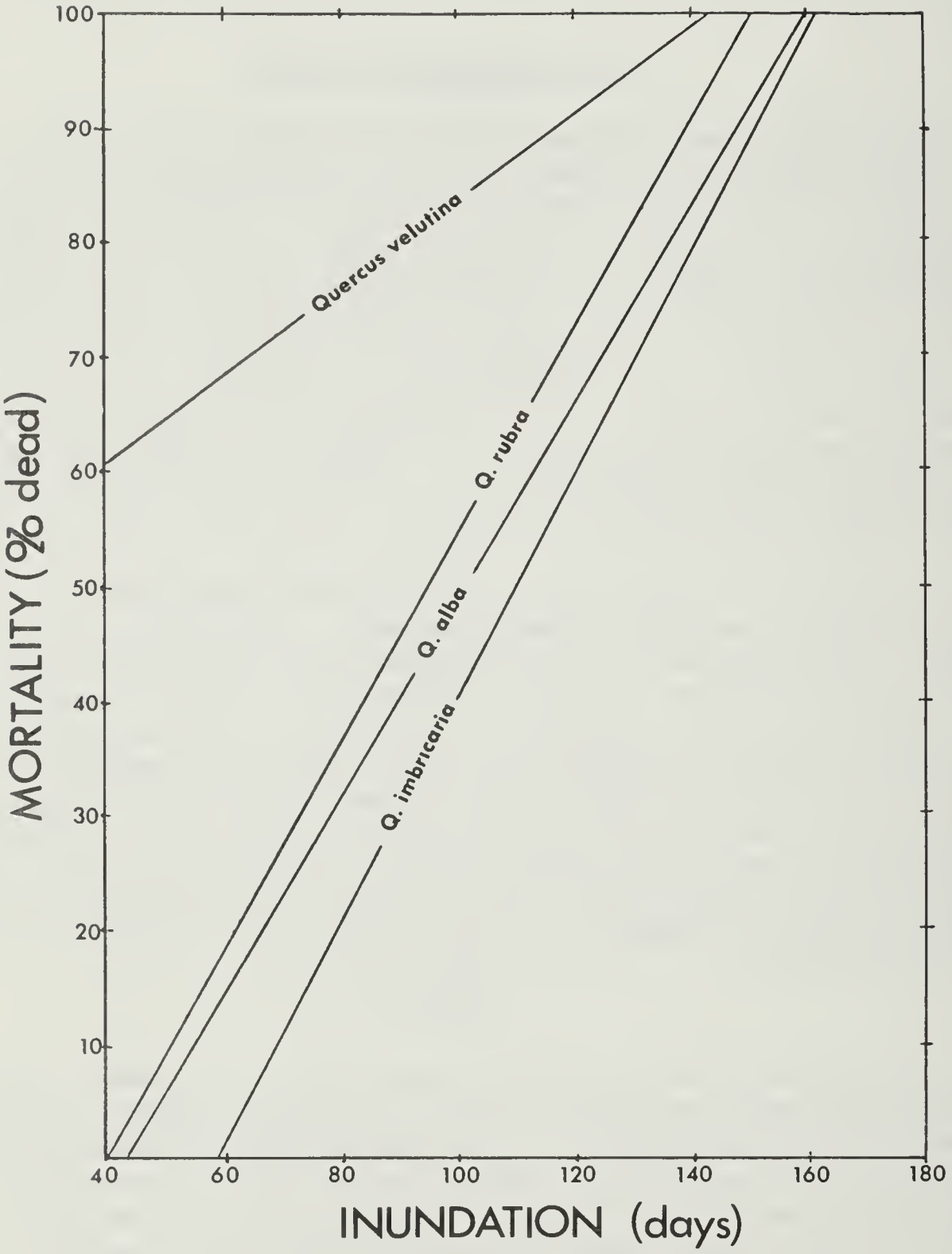

FIG. 1. Linear regression of percent dead vs. days of flooding for Quercus velutina, Q. rubra, Q. alba, and Q. imbricaria.

All Quercus velutina and Carya tomentosa (Mockernut hickory) found within the flooding increment receiving 70 days flood duration were dead and mortality was noted in Carya ovata (Shagbark hickory), Quercus alba (White oak), and Fraxinus pennsylvanica (Green ash). When the period of inundation reached 110 days, marked mortality was observed in the tree species normally associated with upland areas. These species include Quercus velutina, Q. rubra (Red oak), Q. alba, Carya tomentosa, Sassafras albidum (Sassafras), and Prunus serotina (Black cherry). Severe effects were also observed in Juglans nigra (Black walnut) and Quercus imbricaria (Shingle oak), species known to inhabit natural flood plains, but also occur more commonly on uplands. Effects of the impoundment were also noted in Carya ovata, Fraxinus pennsylvanica and Celtis occidentalis (Hackberry) at this duration. Increased flood duration resulted in increased mortality among upland species. Species of the flood plain, however, were found to be completely tolerant of the conditions imposed by the high water. Acer saccharinum (Silver maple), Salix nigra (Black willow), Populus deltoides (Eastern cottonwood), Acer negundo (Box-elder), Gleditsia triacanthos (Honey locust), and Quercus macrocarpa (Bur oak) showed no ill effects from up to 189 days of continuous inundation. Many trees of these species completed their annual growth cycle despite existing flood conditions throughout the growing season. At the time of the sample in late September, the bases of many of the trees were still under water.

Linear regression equations resulting in a statistically significant fit to the observed data were plotted to describe the mortality of the upland species (Fig. 1 & 2). The differential mortality of species within the genus Quercus was illustrative of the trends observed for all species (Fig. 1). Certain species were observed to tolerate flood conditions better than others. Within Quercus, Q. velutina was shown to be very intolerant to inundation; Q. rubra, Q. alba, and Q. imbricaria, less so, and Q. macrocarpa and Q. bicolor (Swamp white oak) were not adversely affected by the flood conditions (Table 1). A positive relationship between mortality and flood duration resulted within all species showing significant probabilities. A similar relationship of increasing percent mortality with increasing flood duration was observed in Carya with the predominatly upland species C. tomentosa more susceptible to inundation than C. ovata which also occurs in areas of natural riverine flooding (Fig. 2).

DISCUSSION

The current study contributes to the knowledge of the interspecific difference in ability to tolerate flood. Information from the current and previous studies has been combined to group species of similar response to flooding (Table 2). It is apparent that species growing under conditions of periodic natural flooding are much more tolerant than those species which rarely or never are subjected to the stresses of high water conditions.

Quercus velutina proved to be the least tolerant to growing season flood conditions of all species observed in the present study. It was the only species to die from flood related causes generated by inundation of 30-49 days. No live Sassafras albidum or Prunus serotina were found at any

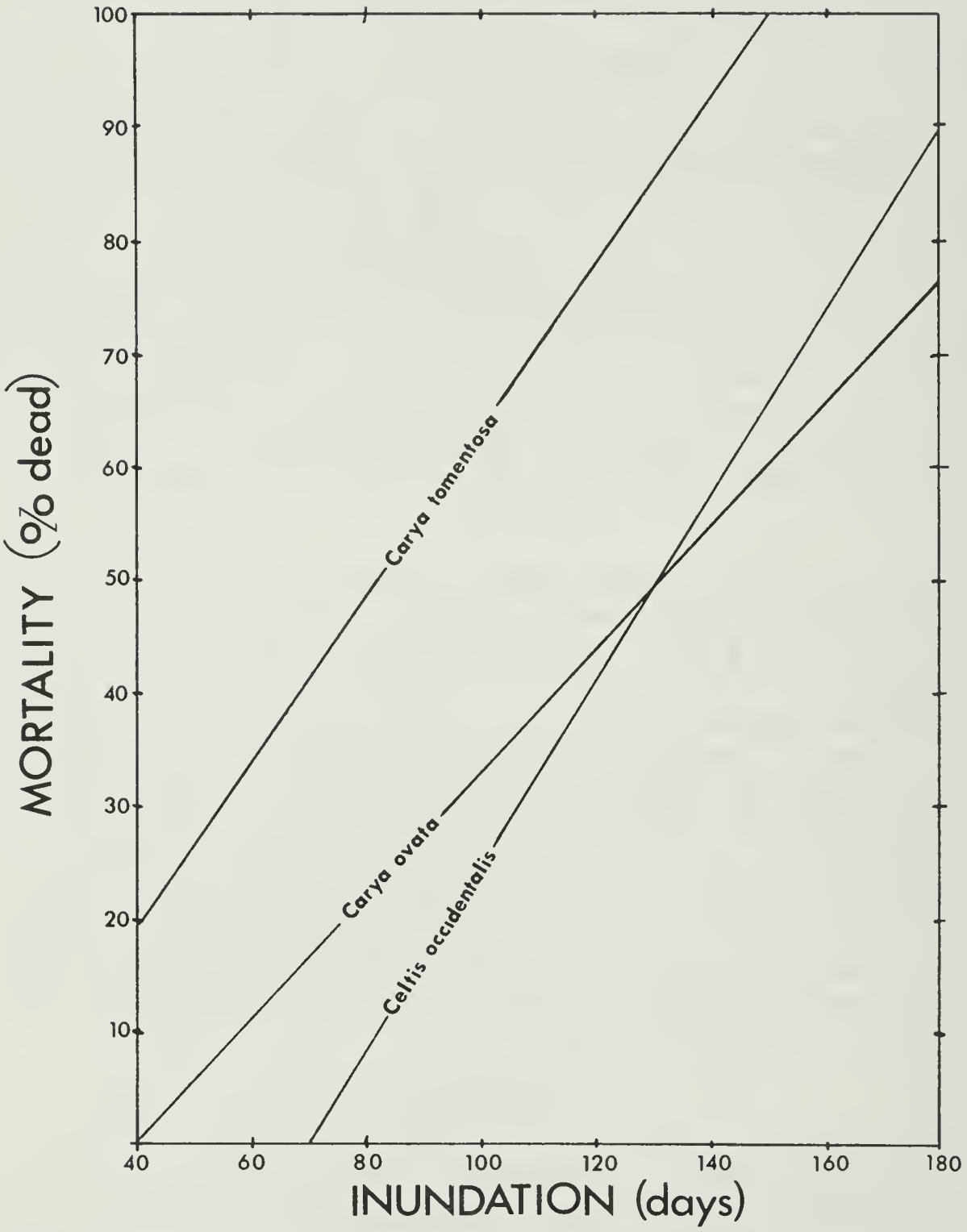

FIG. 2. Linear regression of percent dead vs. days of flooding for Carya tomentosa, C. ovata, and Celtis occidentalis.

TABLE 1. Mortality (% dead) of Illinois tree species to flood duration. Increments were no individuals of the species were found received no value (-).

Species	No. trees sampled	Flood Duration (days) 30-49	50-69	70-89	90-109	110-129	130-149	150-169	170-189	r^2	r	P
Quercus velutina	13	33	-	100	100	100	100	100	100	.498	.706	95%
Quercus rubra	16	0	0	0	100	100	100	100	100	.714	.845	99%
Carya tomentosa	47	0	0	100	65	100	100	100	100	.634	.795	95%
Quercus alba	58	0	-	17	46	83	100	100	100	.899	.948	99%
Cercis canadensis	13	0	100	0	33	-	50	100	-	.222	.471	N.S.
Carya ovata	114	0	0	33	43	31	44	92	62	.765	.875	99%
Quercus imbricaria	14	0	0	0	0	100	100	100	100	.762	.873	99%
Juglans nigra	4	0	-	-	0	100	-	-	100	.640	.800	N.S.
Sassafras albidum	5	0	-	-	-	100	100	-	-	.964	.981	95%
Prunus serotina	3	-	-	-	-	100	100	-	-	-	-	-
Fraxinus pennsylvanica	115	-	-	50	92	39	32	19	18	.563	-.751	N.S.
Celtis occidentalis	37	0	-	0	0	33	45	93	100	.826	.909	99%
Ulmus americana	102	0	0	-	2	0	13	0	9	.297	.545	N.S.
Quercus bicolor	4	0	-	-	-	0	0	-	-	-	-	-
Quercus macrocarpa	13	-	-	0	-	-	-	0	0	-	-	-
Dispyros virginiana	5	-	-	0	-	0	0	-	-	-	-	-
Gleditsia triacanthos	26	-	-	-	0	0	0	0	0	-	-	-
Quercus palustris	4	-	-	-	0	0	-	-	-	-	-	-
Crataegus mollis	6	-	-	-	-	0	0	0	-	-	-	-
Platanus occidentalis	4	-	-	-	-	0	-	0	-	-	-	-
Acer negundo	6	-	-	-	-	-	0	0	0	-	-	-
Populus deltoides	7	-	-	-	-	-	0	0	0	-	-	-
Salix nigra	1	-	-	-	-	-	-	-	0	-	-	-
Acer saccharinum	39	-	-	-	-	-	0	0	0	-	-	-

TABLE 2. Flood tolerance of Illinois tree species. Species are grouped in categories of increasing tolerance to growing season inundation.

INTOLERANT SPECIES (severe effects with < 50 days flooding)

- Quercus velutina (Black oak)
- Prunus serotina (Black cherry)
- Sassafras albidum (Sassafras)

SLIGHTLY TOLERANT SPECIES (most individuals survive > 50 days but < 100 days of flooding)

- Quercus rubra (Red oak)
- Quercus alba (White oak)
- Carya tomentosa (Mockernut hickory)

SOMEWHAT TOLERANT SPECIES (some individuals killed by < 90 days flood and some individuals survived > 150 days inundation)

- Cercis canadensis (Red bud)
- Juglans nigra (Black walnut)
- Quercus imbricaria (Shingle oak)
- Carya ovata (Shagbark hickory)
- Celtis occidentalis (Hackberry)
- Ulmus americana (American elm)
- Fraxinus pennsylvanica (Green ash)

TOLERANT SPECIES (most individuals survived > 150 days inundation)

- Acer saccharinum (Silver maple)
- Populus deltoides (Eastern cottonwood)
- Platanus occidentalis (Sycamore)
- Salix nigra (Black willow)
- Quercus macrocarpa (Bur oak)
- Gleditsia triacanthos (Honey locust)
- Acer negundo (Box-elder)
- Crataegus mollis (Red haw)
- Quercus bicolor (Swamp white oak)
- Diospyros virginiana (Persimmon)
- Quercus palustris (Pin oak)

elevational increment receiving more than 50 days flooding. These species have been previously reported to be highly susceptible to flooding from reservoir inundation (Hall and Smith, 1955).

Quercus rubra, Q. alba, and Carya tomentosa were observed to tolerate 50 days of growing season high water but most succumbed to 100 days of spring and summer flooding. Briscoe (1957) noted the sensitivity to submergence of Quercus rubra and Williston (1959) observed that 60% of pole size or larger individuals of Quercus rubra and Q. alba were killed by 20 days of flooding. These results indicate considerably less tolerance to flooding of these species than found in our study. No previous reference to the tolerance of Carya tomentosa was found.

Several species showed moderate tolerance to growing season inundation. Quercus imbricaria was tolerant of over 100 days flooding but severe effects were noted when inundation continued for longer periods. Mortality was observed in Cercis canadensis, Juglans nigra, Ulmus americana, and Fraxinus pennsylvanica although mortality was not significantly correlated with length of the inundation. Percent mortality of Carya ovata and Celtis occidentalis was positively associated with flood duration and most trees were unable to survive 150 days inundation. Most species within this group have wide distributions, naturally occurring in uplands as well as in areas of moderate flood regimes on the river flood plains (Bell, 1974). Fraxinus pennsylvanica and Ulmus americana (American elm) have been shown to withstand a shallow water-inundation period of about three months (DeGrunchy, 1956). Both species, however, were observed to suffer some ill effects of three-month floods at reservoir sites (DeGrunchy, 1959; Gates and Woolet, 1926) and to severe floods along river margins (Lentz, 1928). Intermediate responses to flooding for Ulmus americana and Celtis occidentalis were noted by Yeager (1949) for mature trees permanently inundated by closure of Alton Dam on the Mississippi River. No previous conclusions have been reported for the flood tolerance of Quercus imbricaria, Juglans nigra, or Cercis canadensis (Red bud).

The most tolerant species observed in the current study occur naturally in portions of the streamside forest which receive considerable inundation under normal river level regimes. Flood durations of 170 days during the rapid growth portion of the annual growing cycle was insufficient to visibly affect 11 species. The high degree of flood tolerance of many of these bottomland species has been noted previously (Green, 1947). Years of permanent inundation is sometimes required to cause death in these species. Yeager (1949) determined that two years would be required to kill all individuals of Quercus palustris, three years for Quercus macrocarpa and Diospyros virginiana, and longer durations for Populus deltoides, Acer saccharinum, and Crataegus spp. Salix nigra has been observed to survive up to 18 years of inundation (Eggler and Moore, 1961).

The data collected in the current study would seem to indicate a limit of 30 days of flooding during the spring and summer to insure survival of upland tree vegetation. Flooding duration is only critical when the flooding occurs in the growing season. Flooding in the dormant season has little effect, even for long durations (Silker, 1948; and Hall and Smith, 1955). Repeated annual flooding during growing periods could result in

mortality of species with durations much less than those received in their first experience under reservoir conditions. Survival of even the most flood-tolerant of species requires at least 55-60% of the growing season to be unflooded (Hall and Smith, 1955). Mature, vigorous individuals suffer less flooding damage than do either seedings or over-mature specimens of the same species (Chandra, 1965; and Lees, 1964). Stabilizing reservoir bank margins with seedlings of flood tolerant species could fail unless precautions are taken to markedly reduce flood period during early development of the trees. Reservoir management to protect the reservoir margin and upstream forests must be based on a knowledge of the limits of flooding tolerance for the tree species making up the forests.

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TWENTY YEARS GROWTH OF LOBLOLLY AND SHORTLEAF PINE PLANTED AT VARIOUS SPACINGS IN SOUTHERN ILLINOIS

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ABSTRACT - Loblolly pine and shortleaf pine were planted at spacings of 4 x 4, 6 x 6, 8 x 8, and 10 x 10 feet on a medium quality site in southern Illinois. Measurements taken after the eleventh, thirteenth, eighteenth, and twentieth growing seasons showed that growth and yield of loblolly pine are greater than shortleaf pine. Close spacings resulted in reduced heights for both species after the thirteenth growing season. At age 18, mortality was excessive in loblolly pine planted 4 x 4. The 8 x 8 spacing resulted in the greatest loblolly pine volume and the 6 x 6 spacing the greatest shortleaf pine volume by age 20. The 10 x 10 spacing appeared to be too wide to produce optimal quantities of merchantable products of either species at age 20.

Loblolly (Pinus taeda L.) and shortleaf (Pinus echinata Mill.) pine have been widely planted in Illinois. Loblolly is about 150 miles north of its natural range, and shortleaf is at the northern limit of its range, naturally occurring in southwestern Illinois on west-facing Mississippi River bluffs. Because of its silvical characteristics, which indicated a better adaptability to the region, shortleaf pine was originally thought to be the species that would best satisfy the land-management objectives; thus, most of the area planted to pine in southern Illinois has been planted in shortleaf.

The early development of loblolly and shortleaf pine plantations in Illinois has compared favorably with plantations in the southeast (Boggess and Gilmore, 1963). But, as the Illinois plantations grow older, the actual growt rate falls below that expected of these species in their natural ranges. In addition, according to a study of a 29-year-old shortleaf plantation (Burkhart and Gilmore, 1967), the stands appear to display accelerated mortality and declining basal area growth.

Disease is active in older stands. Much of the mortality is attributable to Fomes annosus (Fr.) Karst., an indigenous root rot fungus. The incidence of this fungus in Illinois is increasing and may become great enough to make thinning undesirable silviculturally because of the predisposition of suppressed trees to infection.

One of the most difficult forest management problems to solve is to determine the optimum growing space needed for each age and site so as to attain the desired wood products most rapidly. Crown development of forest trees which can be influenced by regulating tree spacing is closely correlated with rate of tree growth and wood quality. In even-aged stands, the average live crown length is inversely related to the number of trees per acre (Wahlenberg, 1960). For loblolly pine, a crown length less than 30% of tree height generally is not sufficient to maintain normal growth and trees with shorter crowns will not respond to release. On the other hand, crown lengths

of 50% of tree height are excessive because they reduce wood quality; a crown length of 40% produces the maximum volume of clear wood.

When total fiber production is important, close spacings have a definite advantage. Until mortality cancels growth, narrow spacings yield greater cubic foot volumes, but wider spacings allow trees to grow to merchantable sizes sooner. There is, however, a point of diminishing returns for spacing beyond which growing space is wasted for much or all of the life of the stand. Ware and Stahelin (1948) reported that for loblolly, slash, and longleaf pine plantations, close (4 x 4 feet) spacing leads to early overcrowding, retarded growth, and death from suppression before the trees reached merchantable size. Spacings wider than 10 x 10 made insufficient use of the growing space during the early years of the plantations.

The contemporary practice is to plant at the wider spacings for financial advantages. Bennett (1963) pointed out that at age 15 a stocking of 600 slash pine trees per acre (about 8 x 9 spacing) yields over 90% of the volume of 1,000 trees (about 6 x 7 spacing). He viewed densities beyond 800 trees as not profitable at an alternative rate of return of 3 percent.

Site and Stand Description

The plantations described in this paper were established at the Dixon Springs Agricultural Center in Pope County in 1949 to study the effect of spacing on the growth and yield of planted loblolly and shortleaf pine. Boggess and Gilmore (1963) have reported on the early growth through age 13. This paper reports growth of the plantations through age 20.

The plantation is growing in soils of the Grantsburg series (Ochreptic Typic Fragiudalfs), which developed under upland forests in 40 to 80 inches of loess deposited on a residuum of sandstone. The Grantsburg soils have a moderately well-developed fragipan at depths of about 30 inches. Both root penetration and movement of moisture are impeded by the fragipan.

The climate is characterized by mild winters, hot summers, and frequent short summer droughts. Rarely are there ice storms or extreme cold. The frost free season averages 195 days annually.

At the time of planting, the area had been abandoned from agriculture approximately 10 years. There was little brush invasion, but a ground cover of broomsedge (Andropogon spp.) had developed on the slightly eroded areas and poverty grass (Aristida dichotoma Michx. and Danthonia spicata (L.) Beauv.) on severely eroded areas. The site was judged to be of medium quality.

One-year-old seedlings used in the study were obtained from the state tree nursery at Jonesboro, Illinois. Loblolly seed came from Maryland and northern Alabama; the shortleaf seed was from an unknown source. Four spacings of 4 x 4, 6 x 6, 8 x 8, and 10 x 10 feet were established in 0.64 acre blocks. A 0.1 acre square sample plot was located in the center of each block for detailed stand measurements. Treatments were replicated four times for loblolly and three times in shortleaf,

except for the shortleaf 4 x 4 spacing, which had two replications. Because of unequal replications, each species was considered as a separate experiment in a randomized, complete-block experimental design.

Field measurements were taken following the eleventh, thirteenth, eighteenth, and twentieth growing seasons. Diameter at breast height (d.b.h.) of each tree on the 0.1 acre sample plots was measured to the nearest tenth-inch, while height of every tenth tree was determined to the nearest foot.

Standard local volume tables were used to compute volumes at ages 11 and 13 but for a number of reasons could not be constructed at ages 18 and 20. Gevorkiantz and Olsen's (1955) composite tables were therefore used for the older ages. They are used by the U. S. Forest Service in southern Illinois without correction and with satisfactory accuracy.

RESULTS AND DISCUSSIONS

Mortality - Survival was nearly uniform over the various spacings for each species, averaging 96 percent for loblolly pine and 90 percent for shortleaf pine at the end of the fourth growing season. However, after 20 growing seasons, mortality was greater at the closer spacings. Table 1 compares stand data for the most recent measurements with those made at the end of the eleventh, thirteenth, and eighteenth growing seasons. Extreme crowding occurred in the 4 x 4 loblolly spacing between the thirteenth and eighteenth years but had not occurred by age 20 in the 4 x 4 shortleaf. The other three spacings of each species had not experienced excessive crowding at age 20 with the possible exception of the 6 x 6 loblolly. Mortality for both species is expected to increase with the passage of time; extreme mortality is expected in the closer spacings of shortleaf pine.

Basal Area - After thirteen growing seasons, the 4 x 4 spacing for loblolly pine had the highest basal area, and total basal area decreased as spacing interval increased. After 20 growing seasons, however, this relationship no longer held true, as the effects of crowding were felt in the 4 x 4 spacing. At the end of the thirteenth growing season, the basal area per acre for 4 x 4 loblolly pine was 170 square feet (Table 1). It increased 6 square feet during the next five years and an additional 6 square feet during the following two years giving a total basal area of 182 square feet per acre at age 20. Mortality had begun to accelerate in the 6 x 6 loblolly spacing, but at age 20 this spacing had the highest basal area. If the mortality continues to advance in the 6 x 6 loblolly spacing, the highest loblolly basal area should be in the 8 x 8 spacing by age 25.

Mortality was not serious at age 20 for any of the shortleaf pine spacings. The highest basal area for this species was found in the 4 x 4 spacing (Table 1).

Before crown closure occurred in this study, basal area growth of both species was determined to a large degree by the number of trees per acre. When trees are young and small and not completely occupying the site, most of them grow at approximately the same height and diameter, and yield increases as spacing interval decreases; thus, closer spacings produce higher basal areas As stands grow older, however, individual tree growth rates slow down in relation to their growing space (Reukema, 1966).

Table 1. Growth and stand data per acre of loblolly and shortleaf pine at the end of four selected growing seasons.

	Loblolly pine				Shortleaf pine			
	4'x4'	6'x6'	8'x8'	10'x10'	4'x4'	6'x6'	8'x8'	10'x10'
	. . . . . Eleventh growing season							
Survival %	92	94	96	94	86	92	95	93
No. of trees	2,497	1,131	654	410	2,321	1,116	645	403
B.A. (sq. ft.)	155	128	106	71	110	93	62	45
Cu. ft. vol.	1,769	1,494	1,205	827	1,032	870	567	406
Av. height (ft.)	27	26	28	27	22	20	20	20
Av. d.b.h. (in.)	3.3	4.4	5.4	5.5	2.8	3.8	4.1	4.4
	. . . . . Thirteenth growing season							
Survival %	90	93	96	92	82	91	95	93
No. of trees	2,420	1,119	654	397	2,237	1,104	645	403
B.A. (sq. ft.)	170	148	130	92	132	115	85	63
Cu. ft. vol.	2,077	1,869	1,799	1,208	1,403	1,230	951	641
Av. height (ft.)	30	32	34	32	25	25	24	24
Av. d.b.h. (in.)	3.5	4.8	6.0	6.4	3.2	4.3	4.8	5.3
	. . . . . Eighteenth growing season							
Survival %	66	85	94	89	73	86	91	92
No. of trees	1,792	1,028	638	389	1,987	1,043	620	397
B.A. (sq. ft.)	176	179	166	127	164	151	123	102
Cu. ft. vol.	2,910	3,290	3,195	2,502	2,363	2,353	1,995	1,701
Av. height (ft.)	39	43	46	45	33	38	38	37
Av. d.b.h. (in.)	4.2	5.7	6.9	7.8	3.9	5.1	6.0	6.9
	. . . . . Twentieth growing season							
Survival %	57	79	87	88	73	86	87	92
No. of trees	1,540	950	590	383	1,987	1,040	590	397
B.A. (sq. ft.)	182	190	172	146	196	173	137	122
Cu. ft. vol.	3,149	4,006	4,108	3,315	2,884	3,206	2,726	2,383
Av. height (ft.)	44	50	53	54	39	45	45	46
Av. d.b.h. (in.)	4.6	6.0	7.2	8.2	4.0	5.3	6.3	7.3

Diameter - The most significant stand parameter measured in the study was d.b.h. During the first 18 growing seasons, average annual diameter increments of loblolly pine increased as spacing interval increased, but the average increments for the last two growing seasons were about the same for all spacings (Table 2). Mortality thinned the 4 x 4 loblolly spacing (Table 1) to the extent that the trees apparently acquired the additional growing space that enabled them to produce more girth. Crowding must be occurring in the other loblolly spacings as evident by increasing mortality (Table 1), resulting in slowing of diameter growth.

Although annual diameter increments of shortleaf pine were greater at the wider spacing for each age period, growth rate decreased after the thirteenth growing season within each spacing. For example, the periodic annual d.b.h. for the first 11 years ranged from 0.25 inch for the 4 x 4 spacing to 0.40 inch for the 10 x 10 spacing. The relative position was the same for the last two years, ranging from 0.05 inch for the 4 x 4 spacing to 0.20 for the 10 x 10 spacing (Table 2). Undoubtedly, crowding occurred for shortleaf at all spacings even though mortality currently is low (Table 1), resulting in a slowing of growth on individual trees.

One site factor that is closely related to diameter growth is available soil moisture. In southern Illinois, soil moisture frequently limits diameter growth because of the character of the soil and because of the loss of moisture via evapotranspiration (Boggess, 1957). It has also been shown that stand density also influences the rate of water absorption (Bay, 1963). Trees at wider spacings usually grow for a longer period during a growing season than trees in dense stands (Boggess, 1957). When moisture is a limiting factor in a stand of trees, that limit may not have been reached in a less dense stand, thus, annual diameter increment will, in all probability, be larger in trees spaced at wider intervals.

Diameter of young trees in this study compared well with those in plantations of similar age in other regions. For example, d.b.h. of trees planted 6 x 6 in this study average 5.7 and 5.1 inches for loblolly and shortleaf pines, respectively, at age 18 (Table 1), whereas d.b.h. of trees spaced the same in the Virginia Piedmont was 5.7 inches for 16-year-old loblolly pine (Kormanik and Hoekstra, 1963).

Height - Average height for both species spaced 4 x 4 was less (significant at the .05 level) at age 18 than heights in the other three spacings. Average height of loblolly pine planted at 6 x 6 also was less (significant at 0.5 level) than those for the two wider spacings (Table 1). The differences are attributed to competition between trees.

The effect of stand density on height growth becomes more pronounced as trees age (Table 1). At age 20, height difference between trees planted at 4 x 4 and those planted at 6 x 6 has increased to 6 feet (significant at .01 level). More than likely, this height difference between the two narrow spacin will continue to increase and greater differences will become evident between the 6 x 6 and the wider spacings.

Cubic-foot Volume - The number of trees per acre has a large influenc on the total cubic feet produced on that acre before the site is completely occupied by the stand.

At age 20, loblolly pine had produced more wood in the 6 x 6 and 8 x 8 spacings (about 4,000 cubic feet) than in the 4 x 4 and 10 x 10 spacings (about 3,200 cubic feet). It is interesting to note that at this age 590 trees on an acre are producing as much volume as 950 trees and 383 trees are producing as much volume as 1,540 trees.

Shortleaf pine is not occupying the site at age 20 as completely as loblolly pine is. The greatest volume for shortleaf pine was about 3,200 cubic feet in the 6 x 6 spacing, followed by the 4 x 4, 8 x 8, and 10 x 10 spacings.

Despite the relatively faster rates of basal area growth shown in the shortleaf pine stands during the past seven years (Table 2), superior height growth largely explains the greater volume obtained in the loblolly pine stands. These findings are consistent with those found by Jackson (1958) in a similar study in Georgia.

Based on cubic feet per tree, the fastest growing trees for both species were those with the widest spacing interval (Table 1). Future measurements are needed, however, to indicate whether the faster rates will eventually narrow the differences in total net volume between the 10 x 10 and 8 x 8 spacings. The 10 x 10 spacing may prove to be too wide because stands that are appreciably understocked cannot be expected to reach normal stocking during a short rotation (Wellwood, 1943). On the other hand, a stocking of 400 trees per acre produced almost as much volume as 600 trees per acre (Bennett, 1963), and a 10 x 10 spacing may eventually become the optimum spacing.

Cord Volume - Our study supports what others have found; namely, at 20 years of age, the yield of wood that meets the minimum specifications for pulpsticks, as measured in standard cords, is influenced by spacing. Our results show that the yield of loblolly pine pulpwood was about the same in the 6 x 6 and 8 x 8 spacings (Table 2), but more than likely the 8 x 8 spacing will yield the greater pulpwood volume within the next three years.

While loblolly pine's growth and yield in southern Illinois are quite encouraging, they are somewhat less than those reported in its natural range. For example, in Louisiana, 18-year-old loblolly pine planted at 8 x 8 spacing averaged 1.9 cords per acre per year (Hansbrough, 1968). In Illinois the growth at this spacing has been 1.7 cords per acre per year (Table 3). The best yield in the Louisiana plantation was 40 cords per acre in 18 years planted at 10 x 10 feet, whereas in our study loblolly produced only 26 cords per acre at 10 x 10 feet in 18 years.

Shortleaf pine in this experiment has produced the greatest volume of pulpwood at the three widest spacings at age 20 (Table 3). It is likely that shortleaf pine growing at either 6 x 6 or 8 x 8 will yield the greatest pulpwood volume within the next five years.

In terms of cord volume, the growth rates found in this 20-year-old Illinois plantation indicate that both species are more valuable if kept on the stump and allowed to grow, presumably increasing in value at almost similar rates. Based on these results, age 20 is not a rational rotation age for most of the spacings.

Table 2. Periodic annual per acre growth for loblolly and shortleaf pine.

	Loblolly pine				Shortleaf pine			
	0-11 years	12-13 years	14-18 years	19-20 years	0-11 years	12-13 years	14-18 years	19-20 years
	. . . . . Basal area (square feet)							
4 x 4	14	7	1	3	10	11	6	16
6 x 6	12	10	6	5	8	11	7	11
8 x 8	10	12	7	3	6	11	8	7
10 x 10	6	10	7	10	4	9	8	10
	. . . . . d.b.h. (inches)							
4 x 4	0.30	0.10	0.14	0.20	0.25	0.30	0.14	0.05
6 x 6	0.40	0.20	0.18	0.15	0.35	0.25	0.16	0.10
8 x 8	0.49	0.30	0.18	0.15	0.37	0.35	0.24	0.15
10 x 10	0.50	0.45	0.28	0.20	0.40	0.45	0.32	0.20
	. . . . . Volume (cubic feet)							
4 x 4	161	154	167	120	94	185	192	260
6 x 6	136	187	287	358	80	180	225	427
8 x 8	109	297	279	456	52	192	209	365
10 x 10	75	190	259	406	34	117	212	341

Table 3. Cord volume per acre for loblolly and shortleaf pines at the end of 18 and 20 growing seasons.

	Loblolly pine		Shortleaf pine	
	18 years	20 years	18 years	20 years
4 x 4	20a	25a	14c	21a
6 x 6	29b	36b	20b	29b
8 x 8	31b	39b	18b	27b
10 x 10	26c	34c	16c	29b

Within an age group for each species, a is significantly different from b and c at the .01 level and b is significantly different from c at the .05 level.

SUMMARY

The following conclusions may be drawn from results of the measurements taken at the end of 20 growing seasons.

(1) This study revealed no reason why loblolly pine and shortleaf pine plantations cannot continue to be used to reforest old fields in southern Illinois. Both species showed satisfactory growth during the first 20 years, even though shortleaf is at the limit and loblolly is beyond the natural range of the species.

(2) Management plans can be designed to use tree spacing as the principle silvicultural tool for eliminating or postponing the need for thinning and to control stand density. Tree growth and development in southern Illinois pine plantations can also be influenced from establishment by carefully planting trees of high genetic quality from appropriate seed sources.

(3) Growth and yield of loblolly pine is superior to shortleaf pine at age 20.

(4) Shortleaf pine yields its greatest volumes at a planting spacing of at least 6 x 6 but probably not wider than 8 x 8 feet at age 20.

(5) Although for pathological reasons, the maximum practical rotation for these southern pines in Illinois may be shorter than those customarily used in the South, the growth rate of trees in the experimental plantation indicates that a rotation of 20 years is too short. Our data show that this a very vigorous stage of development, adding volume at very high rates.

(6) A spacing interval as close as 4 x 4 for loblolly pine is not to be recommended, as excessive mortality will occur at an early age. Competition and overcrowding are so acute after 20 growing seasons that average height is significantly shorter at this spacing. Low vigor and extremely high mortality predisposes a stand to possible insect and disease epidemics. Yield is low at this spacing, and any thinning would be precommercial, thus adding materially to the cost of producing the forest crop.

(7) The 10 x 10 spacing appears to be too wide to produce optimal quantities of merchantable products at age 20. These stands have apparently not fully utilized the potential productive capacity of the site up to this time. With continuing faster growth rates, it appears that this spacing may still develop stands that are near optimum as final rotation age is approached.

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AN ANALYSIS OF THE FISH FAUNA OF THE EMBARRAS RIVER IN CHAMPAIGN COUNTY, ILLINOIS

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ABSTRACT. Thirty of the thirty-seven recorded species of fish presently inhabit the Embarras River in Champaign County, Illinois. A comparison of quantitative data available from 1950-51 and 1970-71-72 yields evidence for increases in silt, soft-bottom tolerant species and decreases in those species not favoring this type of habitat. Six species, including the northern pike, gizzard shad, bluegill, orange-spotted sunfish, largemouth bass, and dusky darter, were not collected prior to 1970.

INTRODUCTION

The fishes of the Embarras River in Champaign County, Illinois, have been collected and studied for over seventy years. Forbes and Richardson (1908) collected during the period of 1882-1901. Thompson and Hunt (1930) studied the Embarras River in even greater detail. Menzel (1952) studied the succession of the fishes of the Embarras River compiling quantitative data on species present at various collecting stations in Champaign County. Larimore and Smith (1963) analyzed changes in the streams and in the fish fauna of Champaign County. In their study of the fishes of the Embarras River basin, the Illinois Department of Conservation did not sample the headwaters region (Lopinot, 1968). However, the distribution of fishes of this headwaters region was recently studied by students at the University of Illinois (Haverkamp and Hansen in undergraduate research reports in 1970 and 1971, respectively).

In most of the previously listed studies, only the presence of each species was reported rather than the numbers of individuals collected of each species. A comparison of presence-absence data would yield minimal information concerning faunastic response to environmental change. The data collected by Haverkamp and Hansen in the two most recent studies was quantitative in nature and, when supplemented with data collected in 1972, can be compared to the data of Menzel's (1952) study. In this paper, an attempt will be made to document a sequence of changes in the fish fauna through time in this region of the Embarras River and account for any such changes.

MATERIALS AND METHODS

Menzel (1952) designated nine collecting stations in Champaign County. Fishes collected by Haverkamp and Hansen in 1970 and 1971, and those collected in 1972 were taken from Menzel's nine original collecting stations. Since Menzel's collecting period spanned several seasons and the number of fish collected was large, the data of 1970-71-72 was combined for a more accurate comparison. All of the recent samples were taken using small-mesh minnow seines. The vast majority of the fish collected in 1972 were determined in the field and released alive. All recent collections were biased in favor of periods of low or average water levels as several stations were inaccessable during periods of high water. Sampling at times of low water levels would yield a higher proportion of the total population since the fish population would be more concentrated (Paloumpis, 1958).

Data on other collections from single stations during 1971 and 1972 was also available. While this data cannot be quantitatively compared to the other complete collections, it can be valuable in noting the occurrence of species not reported in the other studies.

RESULTS

A comparison of presence-absence data on fishes of this region from all available studies (Table 1) yields only relatively minor changes in the fish fauna through time. A comparison of those studies where quantitative data was available (Table 2) indicates differences in quantity in several of the species. Conversion to a measure of relative abundance (Table 3) allows a more accurate means of comparison. Any difference in relative abundance for a particular species can be considered in light of environmental changes that have occurred during this time period. A brief discussion of each species reported from the Embarras River in Champaign County follows.

An Annotated List of Fish

A single specimen of the American eel, Anguilla rostrata, was reported from this region of the Embarras River by Thompson and Hunt (1930), but this species has not been taken since. However, Larimore and Smith (1963) noted that this particular specimen had been collected in adjacent Douglas County rather than in Champaign County.

The gizzard shad, Dorosoma cepedianum, was represented by a single specimen collected in April of 1972. This species was previously listed as being present in a tributary of the Embarras River in Champaign County by Larimore and Smith (1963). However, this tributary joins the river in Douglas County rather

Table 1. Species reported from the Embarras River in Champaign County, Illinois.

Species	Forbes & Richardson (1908)	Thompson & Hunt (1930)	Menzel (1952)	Larimore & Smith (1963)	1970	1971	1972
Anguilla rostrata	-	+	-	-	-	-	-
Dorosoma cepedianum	-	-	-	-	-	-	+
Esox americanus	-	+	+	+	+	+	+
Esox lucius	-	-	-	-	-	+	-
Campostoma anomalum	-	+	+	+	+	+	+
Cyprinus carpio	-	+	+	+	-	+	+
Ericymba buccata	+	+	+	+	+	+	+
Notemigonus crysoleucas	-	+	+	+	+	+	+
Notropis atherinoides	-	-	-	+	-	-	-
Notropis chrysocephalus	-	-	+	+	+	+	+
Notropis spilopterus	-	+	+	+	+	+	+
Notropis stramineus	-	+	+	+	+	+	+
Notropis whipplei	-	+	-	+	-	-	-
Notropis umbratilis	-	+	+	+	+	+	+
Phenacobius mirabilis	+	-	+	+	+	+	+
Pimephales notatus	+	+	+	+	+	+	+
Semotilus atromaculatus	-	+	+	+	+	+	+
Carpiodes cyprinus	-	+	+	-	+	+	+
Catostomus commersoni	-	+	+	+	+	+	+
Erimyzon oblongus	+	+	+	+	+	+	+
Minytrema melanops	-	-	-	-	-	+	+
Moxostoma erythrurum	-	+	+	+	-	-	-
Ictalurus melas	-	+	-	-	+	-	-
Ictalurus natalis	-	-	+	+	+	+	+
Fundulus notatus	+	+	+	+	+	+	+
Aphredoderus sayanus	-	+	-	+	+	+	-
Lepomis cyanellus	+	+	+	+	+	+	+
Lepomis humilis	-	-	-	-	-	+	+
Lepomis macrochirus	-	-	-	-	+	+	+
Lepomis megalotis	-	+	+	+	+	+	+
Micropterus salmoides	-	-	-	-	-	+	-
Pomoxis annularis	+	-	-	-	+	+	-
Etheostoma blennioides	-	+	-	-	-	-	-
Etheostoma caeruleum	-	+	+	+	-	-	-
Etheostoma nigrum	+	+	+	+	-	+	+
Percina maculata	-	-	+	+	-	-	-
Percina sciera	-	-	-	-	-	-	+

Table 2. The total number of fish collected per species from the studies of the Embarras River where quantitative data was available.

Species	Menzel (1952)	1970	1971	1972	Total of 1970-71-7
Esox americanus	1	3	5	1	9
Campostoma anomalum	377	215	213	71	499
Cyprinus carpio	1	0	4	2	6
Ericymba buccata	2875	146	306	99	551
Notemigonus crysoleucas	2	29	81	29	139
Notropis chrysocephalus	99	2	8	4	14
Notropis spilopterus	81	2	158	5	165
Notropis stramineus	894	69	290	93	452
Notropis umbratilis	336	285	541	138	964
Phenacobius mirabilis	2	12	4	1	17
Pimephales notatus	2123	133	284	111	528
Semotilus atromaculatus	893	484	185	131	800
Carpiodes cyprinus	4	1	1	8	10
Catostomus commersoni	50	75	1	25	101
Erimyzon oblongus	152	51	11	9	71
Minytrema melanops	0	0	1	2	3
Moxostoma erythrurum	1	0	0	0	0
Ictalurus melas	0	1	0	0	1
Ictalurus natalis	1	15	6	3	24
Fundulus notatus	42	76	472	5	553
Aphredoderus sayanus	0	1	7	0	8
Lepomis cyanellus	22	33	116	29	178
Lepomis humilis	0	0	106	16	122
Lepomis macrochirus	0	22	81	17	120
Lepomis megalotis	38	12	21	22	55
Micropterus salmoides	0	0	1	0	1
Pomoxis annularis	0	1	5	0	6
Etheostoma caeruleum	6	0	0	0	0
Etheostoma nigrum	229	0	2	1	3
Percina maculata	8	0	0	0	0
Percina sciera	0	0	0	1	1
Total no. of specimens	8238	1668	2910	823	5401
Total no. of species	23	22	26	24	28

Table 3. Relative abundance of species, expressed as percentages of the number of fish collected per species, as reported from the studies of the Embarras River where quantitative data was available.

Species	Menzel (1952)	1970	1971	1972	Total of 1970-71-72
Esox americanus	0.01	0.18	0.17	0.12	0.16
Campostoma anomalum	4.58	12.89	7.32	8.63	9.24
Cyprinus carpio	0.01	0.00	0.13	0.24	0.11
Ericymba buccata	34.90	8.75	10.51	12.02	10.20
Notemigonus crysoleucas	0.02	1.74	2.78	3.52	2.57
Notropis chrysocephalus	1.20	0.12	0.28	0.49	0.26
Notropis spilopterus	0.98	0.12	5.43	0.61	3.06
Notropis stramineus	10.85	4.14	9.96	11.30	8.37
Notropis umbratilis	4.07	17.09	18.59	16.77	17.85
Phenacobius mirabilis	0.02	0.72	0.13	0.12	0.31
Pimephales notatus	25.77	7.97	9.76	13.49	9.77
Semotilus atromaculatus	10.84	29.02	6.36	15.92	14.81
Carpiodes cyprinus	0.05	0.06	0.03	0.97	0.18
Catostomus commersoni	0.61	4.50	0.03	3.04	1.87
Erimyzon oblongus	1.84	3.06	0.38	1.09	1.31
Minytrema melanops	0.00	0.00	0.03	0.24	0.06
Moxostoma erythrurum	0.01	0.00	0.00	0.00	0.00
Ictalurus melas	0.00	0.06	0.00	0.00	0.02
Ictalurus natalis	0.01	0.90	0.21	0.36	0.44
Fundulus notatus	0.51	4.56	16.22	0.61	10.24
Aphredoderus sayanus	0.00	0.06	0.24	0.00	0.15
Lepomis cyanellus	0.27	1.98	3.99	3.52	3.29
Lepomis humilis	0.00	0.00	3.64	1.94	2.26
Lepomis macrochirus	0.00	1.32	2.78	2.06	2.22
Lepomis megalotis	0.46	0.72	0.72	2.67	1.02
Micropterus salmoides	0.00	0.00	0.03	0.00	0.02
Pomoxis annularis	0.00	0.06	0.17	0.00	0.11
Etheostoma caeruleum	0.07	0.00	0.00	0.00	0.00
Etheostoma nigrum	2.78	0.00	0.07	0.12	0.06
Percina maculata	0.10	0.00	0.00	0.00	0.00
Percina sciera	0.00	0.00	0.00	0.12	0.02

than in Champaign County and was not included in any of the other studies. Although not reporting this species in Champaign County, Lopinot (1968) did report it in adjacent Douglas County as well as in several other locations downstream.

The grass pickerel, Esox americanus, represented a very small percentage of the total fish collected and was found only at the two stations in which deeper water was present.

The northern pike, Esox lucius, was represented by a single specimen collected by seine on November 21, 1971. The specimen exceeded four pounds in weight and was preserved in the University of Illinois collection. Lopinot (1968) reported no northern pike anywhere in the Embarras River basin in 1967. Northern pike had not previously been reported in Champaign County and this individual is believed to be a county record. This individual possibly entered this county as a result of post-1967 stocking of this species downstream, although no documentation exists for any such stocking in the Embarras River basin (Rodney Horner, personal communication).

The stoneroller, Campostoma anomalum, showed an increase in relative abundance since 1950-51. This minnow is listed as prefering swift water, with clean sand or gravel bottoms, and inhabiting riffles (Forbes and Richardson, 1908; Trautman, 1957; Pflieger, 1971). The increase in relative abundance did not seem to be seasonal in nature and could not be correlated with any type of favorable habitat change.

The carp, Cyprinus carpio, represented only a small fraction of the total fish collected in recent years. The individuals captured have usually been juveniles found at stations nearer to the source of the river.

The silverjaw minnow, Ericymba buccata, was the most common species collected (34% of total) by Menzel in 1950-51. The percentage has declined to 10% of the total fish as indicated by recent collections. Smith (1968) noted that the silverjaw minnow had been decimated in the Embarras River basin due to habitat destruction. This species inhabits sandy stretches of small, clear, permanent streams with sand bottoms free from silt (Trautman, 1957; Pflieger, 1971). Siltation would thus create a less favorable habitat.

The golden shiner, Notemigonus crysoleucas, has shown a slight increase in relative abundance since 1950-51. This species is relatively tolerant of turbidity (Trautman, 1957) and should be favored by siltation (Smith, 1968).

The emerald shiner, Notropis atherinoides, was reported only by Larimore and Smith (1963). This species is tolerant of turbidity and many bottom types but is usually associated only with larger lakes and rivers (Forbes and Richardson, 1908).

The emerald shiner was not reported from the Embarras River basin in 1962 and was found in only 20% of the collecting stations, although not in Champaign County, in 1967 (Lopinot, 1968). It is possibly the water depth requirement that limits the distribution and numbers of this species in the Embarras River.

The striped shiner, Notropis chrysocephalus, has decreased in relative abundance since 1950-51. Although this species is somewhat tolerant of turbidity, lower stream gradients, and silted bottoms, the striped shiner usually prefers clear streams with gravel, bedrock, or sand bottoms (Trautman, 1957).

Recent collections showed that the relative abundance of the spotfin shiner, Notropis spilopterus, varies seasonally. Combined data from recent collections indicate an increase in relative abundance of this species since 1950-51. Trautman (1957) noted that the spotfin shiner is tolerant of turbidity, siltation, and certain pollutants.

The sand shiner, Notropis stramineus has remained a common species in the Embarras River with little change in relative abundance since 1950-51.

The steelcolor shiner, Notropis whipplei, was reported by Thompson and Hunt (1930) and by Larimore and Smith (1963) but was not found in recent collections. Pflieger (1971) reported that the steelcolor shiner is less tolerant of turbidity than the spotfin shiner. The steelcolor shiner has been reported from the Embarras River in adjacent Douglas County (Lopinot, 1968) and may only come upstream when conditions are temporarily favorable.

The redfin shiner, Notropis umbratilis, has seen a dramatic increase in relative abundance since 1950-51. The redfin shiner is known to be tolerant of turbidity, siltation (Trautman, 1957), and pollution (Thompson and Hunt, 1930).

The suckermouth minnow, Phenacobius mirabilis, has remained a rarer species in the Embarras River in Champaign County.

In spite of its preference for headwater regions and its resistance to pollution (Thompson and Hunt, 1930), the bluntnose minnow, Pimephales notatus, has decreased in relative abundance from 25.7% in 1950-51 to 9.7% of the total fish fauna in recent years. This species is usually found in quiet water over soft bottoms (Larimore, Pickering, and Durham, 1952) but shows a preference for pools with sand bottoms rather than silt-bottomed headwaters (Zach, 1967).

The creek chub, Semotilus atromaculatus, has increased in relative abundance since 1950-51. This pollution-resistent, headwaters species (Thompson and Hunt, 1930) would benefit from siltation as this factor would create more favorable habitat (Smith, 1968).

The quillback, Carpiodes cyprinus, was present in low quantities in each of the years studied. All of the recently collected specimens were under six inches in length.

The white sucker, Catostomus commersoni, showed a slight increase in relative abundance since 1950-51. The white sucker is known to tolerate a wider range of environmental conditions than any other species of sucker. Migration would account for the seasonal differences in relative abundance seen in the data of recent collections (Trautman, 1957).

The creek chubsucker, Erimyzon oblongus, although listed by Smith (1968) as a species which should be favored by siltation, showed a decrease in relative abundance since 1950-51. However, Trautman (1957) described the habitat of the creek chubsucker as clear streams of moderate and high gradients and noted a decrease in abundance of this species in those Ohio streams that had increased in turbidity. Thus, the turbidity of this region of the Embarras River could be the limiting factor for this species.

The spotted sucker, Minytrema melanops, has been listed as being decimated in the Embarras River basin and had not been reported from the Embarras River in Champaign County prior to 1968 (Smith, 1968). This species is present at several locations in the Embarras River to the scuth of Champaign County (Lopinot, 1968). In the recent collections, three specimens were taken; two juveniles and one adult of about sixteen inches in length. Smith (1968) noted that this species was decreasing its range in Illinois. The presence of the spotted sucker further upstream may indicate a reversal of this trend.

The golden redhorse, Moxostoma erythrurum, was reported by Thompson and Hunt (1930), Menzel (1952), and Larimore and Smith (1963). All three of these studies reported this species only at the station furthest downstream at the Champaign-Douglas County line. Menzel (1952) reported only a single specimen in his study. The golden redhorse is a larger-river species that is tolerant of turbidity but prefers rocky or gravelly bottom types (Trautman, 1957). This species would be limited by appropriate bottom type in this region of the Embarras River and thus would not be expected to be a common species.

The black bullhead, Ictalurus melas, was represented by a single fourteen-inch specimen captured by Haverkamp in 1970. This species was reported prior to this only by Thompson and

Hunt (1930). The low numbers of this species in what appears to be optimum habitat was noted by Smith (1968). The factors involved in the maintenance of the low population level of this species are not known at this time.

The yellow bullhead, Ictalurus natalis, has shown a very slight increase in relative abundance since 1950-51. The habits of the yellow bullhead making it difficult to capture by seine have been noted (Larimore, Pickering, and Durham, 1952). Thus, the population level of this species may be greater than the seining data indicate.

The large increase in the relative abundance of the blackstripe topminnow, Fundulus notatus, since 1950-51 can possibly be attributed to increased siltation that would create more favorable habitat for this species (Smith, 1968). Seasonal variation in relative abundance was seen in the data from the recent collections.

The pirate perch, Aphredoderus sayanus, has been reported from the Embarras River in Champaign County since 1930. The population level is extremely low, although this region should represent favorable habitat for this species (Thompson and Hunt, 1930; Smith, 1968). The pirate perch was not collected in the Embarras River basin in 1967 and was reported at only one location in 1962 (Lopinot, 1968). The factors maintaining this low population level are not known.

The green sunfish, Lepomis cyanellus, has increased in relative abundance since 1950-51. This species is tolerant of turbidity and siltation (Trautman, 1957) and should be favored in this region.

The orangespotted sunfish, Lepomis humilis, had not been reported from the Embarras River in Champaign County prior to 1971. This species was first collected in the summer of 1971 and these specimens were deposited in the Illinois Natural History Survey collection. Lopinot (1968) reported one individual in 1962 and two individuals in 1967 in the Embarras River basin. In 1971, the orangespotted sunfish made up 3.6% of the total collection. This species was noted by Smith (1968) as benefiting from siltation. However, Smith noted that this species maintained low population levels. Apparently the factor or factors that maintained a low population level has now allowed the orangespotted sunfish to increase in numbers. Young of the year were noted in the fall of 1971.

The bluegill, Lepomis macrochirus, has spread up the Embarras River and increased in numbers during the 1960's. Bluegills were not reported in the Embarras River in Champaign County in 1963 (Larimore and Smith, 1963). Lopinot (1968) reported bluegills at two locations (10% of the stations) in the southern quarter of the Embarras River basin in 1962 and

reported bluegills at twelve locations (44% of the stations) throughout the Embarras River basin in 1967. In recent years, bluegills made up 2.2% of the fish collected.

The longear sunfish, Lepomis megalotis, was first reported from the Embarras River in Champaign County by Thompson and Hunt (1930). This species has shown a slight increase in relative abundance since 1950-51, although it is known to be intolerant of excessively turbid conditions (Trautman, 1957).

The largemouth bass, Micropterus salmoides, was represented by a single specimen collected by Hansen in 1971. The largemouth bass had not been reported from the Embarras River in Champaign County prior to this collection, although this species had been reported in small quantities in a few locations in the remainder of the Embarras River basin (Lopinot, 1968).

The white crappie, Pomoxis annularis, had been reported by Forbes and Richardson (1908) but had not been collected again until 1970 when Haverkamp reported a single specimen. Recent collections indicate that the population level of this species is quite low, although it is tolerant of turbidity and siltation (Trautman, 1957; Pflieger, 1971). The low population level in this region may be a reflection of the small size of the river and competition from sunfishes (Trautman, 1957).

The greenside darter, Etheostoma blennioides, was reported only by Thompson and Hunt (1930). This species is usually associated with clear, moderate- or high-gradient streams often in swift riffles over a gravel or rubble bottom (Thompson and Hunt, 1930; Trautman, 1957), conditions which are now unavailable in this region of the Embarras River. Trautman (1957) also noted a decrease in the abundance of this species in certain Ohio streams that had increased in turbidity.

The rainbow darter, Etheostoma caeruleum, was reported as recently as 1963 (Larimore and Smith, 1963) but was missed in recent collections. The habitat requirements of this species are similar to that of the greenside darter (Trautman, 1957; Pflieger, 1971) which was also missing. Siltation would account for the decline in the rainbow darter population.

The johnny darter, Etheostoma nigrum, has shown a pronounced decrease in relative abundance since 1950-51. The johnny darter is known for its resistance to pollution (Thompson and Hunt, 1930) and is relatively tolerant of turbidity but avoids streams that are excessively turbid and silty (Trautman, 1957; Pflieger, 1971).

The blackside darter, Percina maculata, was reported by Menzel (1952) and Larimore and Smith (1963) but was not captured in recent collections. Lopinot (1968) reported the blackside

darter from several localities on the Embarras River downstream from Champaign County including adjacent Douglas County. This darter is known to tolerate mild turbidity provided a sufficient current is present (Trautman, 1957). It is possible that this darter enters Champaign County only when current conditions are favorable and may have been missed in recent collections for this reason.

The dusky darter, Percina sciera, was represented by a single adult specimen collected in the winter of 1972. This individual was identified in the field and then released. This species had not previously been reported from the Embarras River in Champaign County, although it had been collected in adjacent Douglas County (Page and Smith, 1970). The dusky darter has been described as a species characteristic of clear, low-gradient streams with silt-free sand or gravel bottoms (Pflieger, 1971). This species is known to migrate downstream to the deeper water of river channels in the winter (Page and Smith, 1970). The factors allowing its presence in this shallow, silty region of the Embarras River are not known.

DISCUSSION

Although not supported by actual data, it is generally assumed that the siltation of the Embarras River has increased during the past forty years (Larimore and Smith, 1963; Smith, 1968, 1971). P. W. Smith (1968) studied the factors involved in the changes in the fish fauna of the Embarras River drainage and found that siltation was a very important factor in such faunastic change. He noted that while siltation decimated the populations of certain species, it could be assumed that certain other species should be favored by this change, although no data was available to confirm this at the time. The results of this study confirm Smith's assumption showing an increase in relative abundance of carp, golden shiner, redfin shiner, creek chub, yellow bullhead, blackstripe topminnow, green sunfish, orange-spotted sunfish, and bluegill since 1950-51. Also gizzard shad, black bullhead, pirate perch, largemouth bass, and white crappie are now present in small quantities. All of the previously listed species show some degree of preference or tolerance for silt bottoms (Trautman, 1957; Pflieger, 1971) as are found in this region of the Embarras River. These species were all listed by Smith (1968) as species which should benefit from the conditions created by siltation.

Siltation and stocking of game fish downstream have created a situation beneficial to local fishermen with northern pike, pickerel, yellow bullhead, white crappie, largemouth bass, bluegill, green sunfish, and longear sunfish present within this region of the Embarras River.

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BENEFITS DERIVED FROM WATER QUALITY MANAGEMENT PLANNING

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ABSTRACT

The requirement of water quality management planning for eligibility for federal construction grant funds has added a new dimension to water pollution control. Effective planning can provide for significant cost savings in the construction of wastewater treatment facilities. Additional benefits such as improved operation and treatment efficiencies result from optimizing the pollution control facilities. The rationale behind these planning requirements is discussed and examples of the benefits are presented.

WATER QUALITY MANAGEMENT PLANNING

Water quality management planning is a recent innovation in the area of water pollution control. This planning effort has been initiated for several reasons. Camp, Dresser and McKee conducted a study of the Federal Construction Grants Program at the request of the Office of Management and Budget of the federal government. This study indicated that the construction grants money was not being invested in a cost-effective manner. Some of the monies were being used for construction of treatment facilities that yielded a very minor improvement in water quality. The use of this money for improved treatment of more severe discharges would have had a marked improvement on the water quality. There did not appear to be any organized approach to the expenditure of these funds to achieve maximum improvement of water quality.

As more emphasis has been placed on water quality problems, the need for planning has become more apparent to all involved. The State of New York undertook an extensive planning effort beginning in the mid 60's. Their experience has reinforced the need for more comprehensive analysis of the problem and the development of an organized approach for eliminating the sources of water pollution that have the most severe effect on the receiving waters. These experiences, plus the intuition of many people involved in the water pollution control program, have led to the conclusion that some type of orderly planning is necessary.

The Federal EPA has incorporated planning into their construction grants program. The rules and regulations relating to grants for water pollution control (Federal Register, 1970) specifically require the development of basin and metropolitan/regional water quality management plans in order for specific projects to be eligible for federal construction grants. These rules and regulations were instituted in July of 1970. Recognizing that many states and/or regions did not have adequate plans, a procedure for the development and use of interim plans was provided. However, by July 1, 1974 the final basin and metropolitan/regional plans must be developed and certified if continued support from construction grants program is to be expected.

Not only is this planning required for meeting federal guidelines, but it is also necessary for the orderly development of the State of Illinois water quality control program. Judicious use of the state's water resources require consideration of the capacity of streams to assimilate wastes while maintaining water quality compatible with water uses. This objective will be achieved only by a thorough analysis of the stream's capacity for waste assimilation under the constraints imposed by the water quality standards and the complete inventory of the existing as well as projected waste loads. The assimilative capacity of the stream will dictate the degree of waste-water treatment or other controls that will be required for the present as well as future conditions. This type of planning is currently not available. Most of the water resources planning that has been conducted has been oriented toward the water uses but not the maintenance of water quality at the current level required by the recently adopted Illinois Pollution Control Board Stream Standards.

Effluent requirements and wastewater treatment plant design is based upon meeting the water quality standards today without adequate knowledge of the effect of future waste loads on the water quality. Therefore, it becomes imperative that projections be made as to the probable development of an area and the associated waste loads. This projected load coupled with the assimilative capacity of the receiving waters provides a guide to the degree of treatment required today as well as in the future. This type of information provides for an orderly phasing of the size of the treatment plants as well as the degree of treatment required to maintain the desired water quality.

Basin Planning

The basin plan provides an overview of the impact of pollution sources and alternative pollution control measures on the receiving water, basic information on stream flows and water quality, and requirements for jurisdictional cooperation at various levels. Because of the scope of these plans, they are the responsibility of the state or of the designated basin planning organization. Since Illinois does not have any basin planning organizations, these plans then become the responsibility of the Illinois Environmental Protection Agency.

The basic purpose of basin planning is the development of a water pollution control strategy that will maintain the desired water quality of

the surface waters of Illinois. This purpose is accomplished for a specific basin by analyzing the assimilative capacity of the stream for various contaminants and allocation of the magnitude of the contaminant input into different reaches of the stream such that the desired water quality is obtained. The assimilative capacity of a given stream at critical flow conditions is fixed. Consequently the increase in waste load associated with an increase in population or industrial activity can exceed the stream's ability to dissipate the waste. Adequate planning on a basin wide basis allows for the orderly development of the necessary control systems for each reach of the stream. Because of lead time of several years being needed to plan, finance, design and construct adequate control systems, one cannot wait until the water quality deteriorates to initiate this activity. An adequate basin plan will provide the means for anticipating the level of treatment or the other control measures that are required for present as well as future conditions.

In preparing basin plans, extensive use will be made of the land use, population, industrial and agricultural planning and projections that have been produced by other state and local planning agencies. It is not the intent that basin planning become involved in land use planning. However, it is essential that this information be available if accurate projections of waste loads and treatment requirements are to be made. There may be areas in the state where this information may be deficient. In these areas, some analysis will have to be made of those factors if adequate basin plans are to be produced.

Interim plans are necessary if pending projects are to receive federal support. The Illinois EPA has undertaken this effort and has received approval on several of the interim basin plans. The Agency has developed a planning section which is currently preparing the necessary interim plans to insure that continued federal support is received.

The final basin plans are more detailed, requiring considerably more manpower than the Agency has available. In order to develop an efficient and effective program for Illinois, Argonne National Laboratory has been contracted to develop a pilot basin plan. Argonne will prepare a model water quality basin plan for the Rock River basin. The plan will meet all applicable federal requirements as described in the U.S. EPA publication, Guidelines: Water Quality Management Planning, dated January 1971. Since the scope of this planning effort is substantial, it is expected that outside consultants will prepare the basin plans for the balance of the state. Argonne is preparing detailed technical specifications suitable for use by these contractors in developing the remaining fifteen water quality basin plans. In addition, Argonne is preparing a manual of procedures to be used by the Agency in managing and supervising water quality planning efforts in Illinois. This manual includes cost estimates for preparing basin plans, recommended management procedures, definition of working relationships with other state agencies, a methodology for selecting basin contractors, sources and location of data necessary for completing basin plans and recommended procedures for involving local representatives in the planning process.

Upon completion of the Argonne pilot study, contracts will be let to qualified applicants for the development of the remaining basin plans. The

Argonne work should be completed in the fall of 1972. Since the deadline date has been extended until July 1, 1974, it is possible for the state to meet the requirements for continued federal support. When these basin plans have been completed, the state will have a sound basis for developing water pollution control systems so that the maximum water quality improvement will be obtained for the available resources.

Metropolitan/Regional Plans

The basin planning activity identifies the total load on the stream and the assimilative capacity of the stream. Knowing what the stream can assimilate, it then becomes possible to allocate loadings for different metropolitan or regional areas. This essentially tells the region the total pounds of pollutant that can be discharged without violating water quality standards. There is no attempt in the basin plan to specify the level of treatment or the type of treatment required.

The metropolitan/regional plans are subsets of the basin plan and are the functional wastewater collection treatment plant elements for the comprehensive area wide plan as set forth in HUD area wide planning requirements. This planning will dictate the number, size, efficiency and location of treatment systems for the regional area that are required in order to satisfy the allotment developed from basin planning. These plans must satisfy the immediate needs as well as the long range needs for water quality management that develop with expanding population and industrial activity.

This planning is the responsibility of the area wide planning offices as designated by HUD. These APO's must develop the necessary plan documents such that federal funding will continue. It is not the purpose of this water quality management planning to undertake land use planning, but to use land use planning and population and industrial projections developed by the area planning agency. If this information is not available, it becomes the responsibility of the area planning agencies to develop it in conjunction with the water quality management planning activity.

The federal government recognized that few metropolitan areas have such local planning completed. There is a provision for interim plans and some of the regions in Illinois have completed their interim plan requirements. To assist the local agencies in this planning effort, the state is providing financial assistance. Most of the local planning agencies are understaffed and underfinanced and cannot conduct the water quality planning on their own. Some, albeit limited, federal funds are available to assist the local agencies in developing the comprehensive plan as required by HUD and EPA.

While the basin plans are an integral part in developing the most cost effective system for controlling water pollution, it is at the regional level where the true savings are found. The basin plan allocates a certain portion of the stream assimilative capacity to the local area. It then becomes the responsibility of the local agency to optimize the control system to meet these allowable loads. It is through the development of

regional water quality management systems that true cost reductions are obtained.

BENEFITS OF REGIONALIZATION

The benefits derived from regional systems are as follows:

Capital costs and operation and maintenance costs are lower per unit quantity of wastewater treated.

Reliability of the treatment system is significantly improved because of multiple process units and the more efficient maintenance program.

Improved operation resulting from more competent operating personnel.

Improved overall process efficiency resulting from adequate facilities and personnel for operation and maintenance.

Capital Costs

Initial costs per unit of treated wastewater are significantly decreased because the size of the treatment plant increases. Smith (1968) analyzed the costs of treatment systems and found that for the activated sludge process, the capital investment per 1,000 gallons of wastewater treated decreased from ten to eleven cents for a one mgd capacity plant to six cents for a ten mgd capacity plant (1967 dollars). The cost savings is due to the economies of scale. Any handbook for estimating construction costs will show that unit costs of material and equipment associated with these processes decreases as the size or quantity of material used increases. This is also true for such costs as engineering fees, performance bonds, etc.

There are many examples one can cite that show savings due to economy of scale. The total cost reduction can be seen from the data from an engineering economic evaluation of regional systems in New York (Metzler, 1971) (See Table 1). Without regionalization the area served by the Albany County Sewer District, comprised of seven municipalities, would have had eight treatment plants. The total capital costs for this nonregional system would be $78,500,000. The proposed regional system would have two plants for the same population, but at a cost of only $53,100,000. This resulted in a capital cost savings of $25,400,000.

Another example, for Rensselaer County Sewer District #1, showed that a regional sewer district would reduce the number of plants from three to one with a cost reduction from $38,940,000 to $32,100,000. The cost saving was not as dramatic, being only $6,840,000. It was, however, significant.

Operation and Maintenance Costs

Cost savings in this category are associated with personnel costs, energy and chemical costs. The number of personnel required is a function

TABLE 1. Cost Comparisons--Regional Systems (New York)

Item	Albany County Sewer District		Rensselaer County Sewer District No. 1	
	Separate Local Systems	Regional System	Separate Local Systems	Regional System
Total capital cost	$78,500,000	$53,100,000	$38,940,000	$32,100,000
First year O & M	1,999,000	1,010,000	861,000	695,000
First year amortization	4,540,000	2,178,000	1,937,000	1,100,000
First year O & M and amortization	6,539,000	3,188,000	2,798,000	1,795,000
Plants	8	1 @ 35 mgd 1 @ 19 mgd	3	1 @ 25.5 mgd
Operating personnel	110	35	51	28
Municipalities	7	7	6	6
Population served	225,000	225,000	101,700	101,400

Source: Metzler, 1971

of the number of plants as well as the size of plants. Using the Albany County example (see Table 1), 110 operating and maintenance personnel are required for the eight plants as compared to only 35 for the two regional plants. Not only is there a cost reduction, but there is also less strain on the reservoir of experienced, qualified operating and maintenance personnel.

Energy and chemical costs are lower for volume consumption. Costs (1967) for electrical energy range from .98 to 2.22¢/kwh for small plants to 0.6 to 1.3¢/kwh for large plants. The cost of chlorine (1967) also decreased with increasing consumption; small plants -- $9.10 to $17.50/100 lb, large plants -- $4.15 to $9.10/100 lb. The purchase of readily available chemicals in bulk quantities always produces a lower unit cost for the chemical.

Summary of Cost Savings

Reduction in the capital amortization and operating and maintenance costs to an annual per capita cost show the real savings per person served by regional systems. Using data reported for New York State, the first year per capita cost for Albany County would be $29 for the nonregional solution compared to $14.20 for the regional system. For Rensselaer County Sewer District #1, the nonregional system would cost a total of $27.60 per capita for the first year compared to $17.70 for the regional system. From these analyses, the savings from regional systems can be very substantial. In urbanized areas, no new systems should be built without a thorough

economic analysis of the potential for regional treatment systems.

It should not be assumed that simply building larger and larger plants necessarily gives the least cost solution. The costs of the interceptor system must be considered. As the interceptor lines become longer, the costs for transporting the wastewater increases. However, there is an optimum size treatment plant, unique to each area, which can be determined by a thorough economic analysis of that area. Therefore, the goal of regionalization is to develop that system, whether it be one or more plants, that will provide the maximum water quality improvement for the minimum dollars spent.

Non-Economic Benefits of Regionalization

The reliability factor for the larger treatment system is improved for two reasons. There is a greater multiplicity of process units in the larger plants so that the shutdown of any one unit causes a smaller incremental increase in load applied to the remaining units. The treatment efficiency is reduced to a lesser degree than in the smaller plants when one process unit may account for half the treatment capacity of the plant. Perhaps an even more important factor is the maintenance. With a larger and experienced maintenance staff, a program maintenance can effectively prevent most failures of process units. When failure does occur, the maintenance staff of a larger plant can be better equipped and trained so that the down time of any unit can be greatly reduced.

Currently there is a shortage of experienced and capable operating personnel. It is generally possible to meet the personnel needs, but unfortunately these operators may be inexperienced and cannot adequately perform the required tasks. The plant efficiency suffers as a result. The proliferation of the smaller treatment plants accentuates this problem by placing a greater demand on the available operators. Many of the small plant operators receive little or no training or assistance necessary to develop operating skills. They continue to operate in the same inadequate fashion from day to day. In the larger plant, the resources are available to obtain at least some experienced operators. It is then possible to provide in-plant training for new employees. The overall operating skills within the plant can be maintained at a high level under these conditions. This problem may ease in the next decade if the federal and state training programs develop as planned.

SUMMARY

The previous discussion has indicated that the benefits of water quality management planning are basically one of developing the most cost effective program to achieve the desired water quality. This means that with the limited amount of public funds available, the goals of water quality can be achieved without exhausting these funds. Every community, as well as the state, has pressing demands for their resources, whether it be for water pollution control, streets and highways, education, etc. The current

heavy tax burden on the citizens of this state requires that those responsible for expenditure of public funds do so in the most cost effective way. The construction of high levels of treatment where it is not warranted is a poor investment of public money. The water quality improvement achieved by this money may be negligible whereas if it had been spent in an area contributing more load to the receiving water, the improvement may have been substantial. There are numerous recorded cases in which certain communities, for one reason or another, had access to large sources of federal and state money. They greatly expanded their treatment facilities with little or no improvement in the receiving stream. The water quality degradation resulted from upstream discharges of gross pollution. Had the money been spent on the upstream discharges, the water quality would have improved markedly without the extensive treatment provided by the more fortunate communities.

The goal of the water pollution effort is to achieve a water quality that will permit use of the water for designated purposes. To treat beyond that level is unwarranted. However, without a complete analysis of the physical and demographic characteristics of the basin, it is not possible to determine what the level of treatment must be to achieve the required water quality standards. It is essential that future development of the area be predicted and this inserted into the analysis for determining the allowable loads from given areas. With this type of analysis the state can be assured of achieving the desired water quality goals with a minimum of economic burden on the taxpayers.

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A PRE-IMPOUNDMENT STUDY OF THE FISH FAUNA OF INDIAN CREEK, DEKALB COUNTY, ILLINOIS

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ABSTRACT

A pre-impoundment study of the fish fauna of Indian Creek was conducted to determine both species composition and distribution patterns. Diversity indices are presented for collection stations. Increased diversity was found at stations having increased water depth. Two headwater cyprinid species are apparently replaced downstream by three other minnow species. The possible consequences of poisoning Indian Creek with rotenone are discussed.

INTRODUCTION

Indian Creek, a tributary of the Fox River, presents a unique opportunity to study the effects of impoundment on a stream in northern Illinois. The headwater area of the creek is the site of a 330-acre recreational lake proposed by the Illinois Department of Conservation (Figure 1). Construction of the lake is scheduled to begin in 1974, and will include rotenone poisoning of the entire headwater drainage to prevent the introduction of *Cyprinus carpio* into the lake (Leo Rock, Department of Conservation, personal communication). Unfortunately, rotenone is not a selective poison for *C. carpio* but is lethal to all other fish species and much of the invertebrate fauna of the creek (Hynes, 1970). The proposed activities will undoubtedly alter the present species composition and distribution patterns.

METHODS

Collections of fish were made at monthly intervals from October, 1971 through October, 1972 except for the month of February, 1972 along the headwaters of Indian Creek at stations that would be affected by the proposed impoundment. The collection of October 5, 1971 was selected for analysis because it contained the largest number of fish collected and was believed to be the most representative sample of the stream's fish fauna. The collections during 1972 were hampered by ice during the winter and by almost continuous high water levels in the spring and summer. The collections were made in an upstream direction using a minnow seine, 5.54 m. in length, having a mesh of 4.7 mm.

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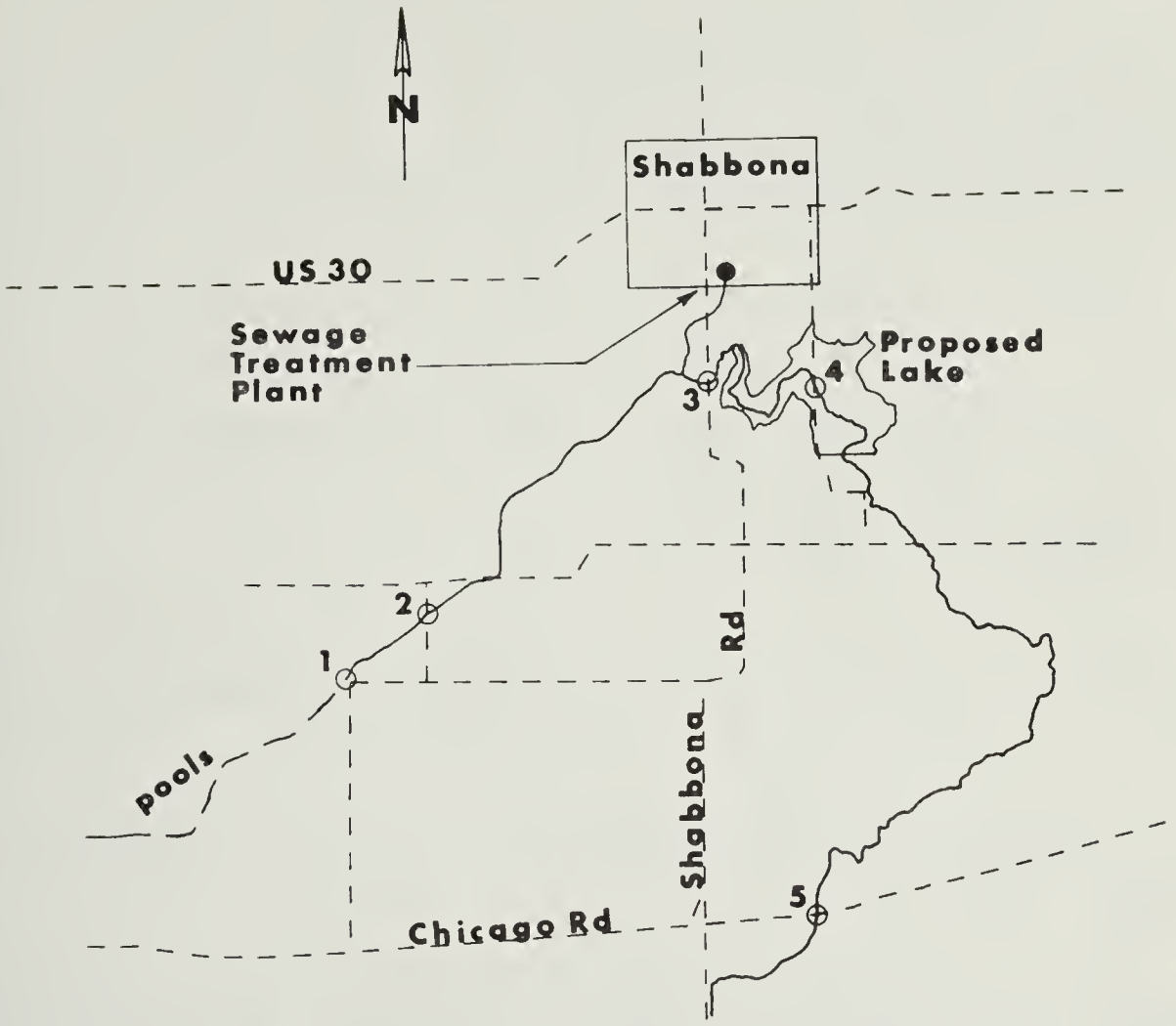

Figure 1. *Headwater area of Indian Creek showing collection stations*

The index of diversity, H', was calculated from the data of Table 1 using the formula

$$H' \approx \frac{1}{N} \left(N \log_{10} N - \Sigma n_i \log_{10} n_i\right)$$

as suggested by Lloyd, Zar, and Karr (1968), where N is the total number of individuals of all species and n_i is the number of individuals of each species. This is an information-theory measure of species diversity based upon both the number of species present and their relative abundance.

THE STUDY AREA

The headwater area of the creek was defined as the 18 km section that extends from station 1 to station 5 (Figure 1). Even at low water levels there was a continuous flow of water throughout this section originating from springs at station 1. Isolated pools, which are fed by field tiles and extend for about 3.5 km. upstream of station 1, are continuous with the head-

TABLE 1. *Characteristics of collection stations, October 5, 1971*

Station	Stream Width, m.	Water Depth, cm.	Water Temperature, ^{0}C	Cover	Substrate
1	.9-1.2	15-30	20	none	silt, gravel
2	.6-3.1	15-65	15	trees, bushes	silt, gravel, rocks
3	1.8-3.1	15-25	15	bushes	silt, gravel, rocks
4	1.8-3.1	15-30	20	none	silt, gravel
5	3.1-3.7	15-90	17	trees, bushes	silt, gravel rocks

water area during periods of high water (Figure 1). These pools were sampled in November, 1971.

The majority of the land drained by the headwaters is utilized for corn and soybean farming and for pasture. There are limited wooded areas present between stations 2 and 5. In addition to draining the above lands, the headwaters also serve as an outlet for the sewage treatment plant of the town of Shabbona. The sewage effluent enters Indian Creek via a small tributary approximately .5 km upstream of station 3.

A description of the collection stations is given in Table 1.

RESULTS

The species composition of the October, 1971 collections is given in Table 2. A total of twenty-five fish species was collected, representing five families. Names of fish species are those used by the American Fisheries Society (1970) except for *Chrosomus erythrogaster,* which follows the suggestion of McPhail and Lindsey (1970). The largest number of species (twenty) was collected at station 5, and the largest total number of specimens (1,583) was collected at station 3.

During other collections, eight additional species were taken: *Hypentelium nigricans, Notropis umbratilis, Moxostoma erythrurum, Micropterus salmoides, Etheostoma flabellare, Percina phoxocephala, P. maculata,* and *Cyprinus carpio. C. carpio* was found only in the series of pools above the headwaters and represented only a small portion of the fish fauna of these pools.

The results of the index of diversity (H') calculations are given in

TABLE 2. *Distribution of species at stations 1 to 5 in October, 1971*

Species	Stations 1	2	3	4	5
Notropis cornutus	63	60	466	549	389
Notropis dorsalis	294	107	441	565	215
Notropis stramineus			8	27	93
Notropis rubellus			2	40	18
Notropis spilopterus				5	33
Rhinichthys atratulus	53	26	1		
Campostoma anomalum	4	4	26	33	58
Chrosomus erythrogaster	92	43	113		
Semotilus atromaculatus	21	49	10	6	50
Pimephales notatus	291	166	473	80	133
Nocomis biguttatus	1	21	34	30	12
Notemigonus crysoleucas			1		
Phenacobius mirabilis				1	
Etheostoma spectabile	20	6	6	4	9
Etheostoma nigrum	8	15	2		5
Etheostoma zonale					7
Catostomus commersoni		2		2	10
Carpiodes carpio					8
Micropterus dolomieui		2		1	4
Lepomis macrochirus				2	2
Lepomis cyanellus		1			4
Ambloplites rupestris					1
Ictalurus natalis				1	1
Ictalurus melas	1		1		
Noturus flavus					1

Table 3. The highest values of H' were found at stations 2 and 5, which also had the greatest water depths (Table 1).

DISCUSSION

The higher diversity found at stations 2 and 5 is probably due to increased habitat diversity permitted by increased water depth at these stations. This is in agreement with Sheldon's (1968) conclusions that increased water depth results in greater species diversity. However, a second conclusion of Sheldon's, that downstream succession involves progressive additions to the headwater fauna rather than replacement, is not supported by the results from Indian Creek. A distinct restriction of *Rhinichthys atratulus* and *Chrosomus erythrogaster* to the upper reaches of the headwaters and an apparent downstream replacement of these species by *Notropis stramineus, N. rubellus,* and *N. spilopterus* were observed (Table 2). The assemblage of species in Indian Creek differs from that of the stream investigated by Sheldon (1968), and the authors suggest that the composition of the fish fauna of a stream influences the pattern of downstream succession, determining the degree of replacement and/or addition which occurs.

TABLE 3. *Index of diversity for stations 1 to 5*

Stations	1	2	3	4	5
N-total number of specimens	847	503	1583	1347	1053
S-total number of species	10	14	13	16	20
H'-index of diversity	.6947	.8409	.6607	.5903	.8496

Larimore and Smith (1963) found increased productivity of fish populations below sources of domestic sewage, perhaps explaining the increased number of specimens collected at station 3. There were no other indications that the sewage effluent from Shabbona had any significant effect on the fish fauna of Indian Creek.

The proposed rotenone poisoning of the entire headwater to eradicate *C. carpio* poses several problems. First, the extensive destruction of the animal fauna of any habitat is the antithesis of the conservation ethic, and second, such extensive faunal destruction is ecologically unsound. *C. carpio* has high reproductive and growth potentials, but both spawning activities and growth are inhibited by the presence of other fish species (Carlander, 1969). The vast reduction in the numbers of fish and variety of species now inhibiting the growth of *C. carpio* might easily permit the few carp that may survive the poisoning or that may be reintroduced into the area to expand their populations to higher levels than existed before the poisoning. Additionally, *C. carpio* is not typically a headwater species. If, however, the proposed impoundment provides a suitable habitat, then this species will certainly find a way in, thus making the poisoning of the headwater futile.

ACKNOWLEDGMENTS

We wish to express our appreciation to Dr. David W. Greenfiels and Dr. Jerrold H. Zar for their helpful comments, and to Leslie Wildrick and Marlena Drew for their assistance in the preparation of the manuscript.

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VASCULAR PLANTS IN AND NEAR ROBERT ALLERTON PARK

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ABSTRACT - 857 species of vascular plants, representing 447 genera in 114 families, have been collected in and near Robert Allerton Park in Piatt County, Illinois. In addition to spontaneously occurring plants, cultivated species have also been included, and the checklist has been annotated to indicate the cultivars and introduced species.

Robert Allerton Park, a recently named National Natural Landmark, is an educational center and research area owned by the University of Illinois and operated as a wildlife preserve, a natural woodland, an example of landscape gardening, and a public park. It is located in the Sangamon River valley, four miles southwest of Monticello, in Piatt County, Illinois (Sec. 21 & 29, T18N, R5E, 3rd PM; Long. 88° 31' W, Lat. 40° 00' N). About half of the 1,500-acre area is accessible to the public, while the remainder is maintained as a nature preserve.

Several plant habitats are involved in the study. The flood plain of the Sangamon River supports a rich, nearly primeval forest with Silver Maple (Acer saccharinum), Sycamore (Platanus occidentalis), Green Ash (Fraxinus lanceolata), and Cottonwood (Populus deltoides) among the common trees. The river bluff areas are dominated by Red Oak (Quercus rubra), Bur Oak (Quercus macrocarpa), and Sugar Maple (Acer saccharum) with Red Elm (Ulmus rubra), Redbud (Cercis canadensis), and Hop-hornbeam (Ostrya virginiana) the common understory species. Most of the upland natural areas are covered with upland forest, where the principal trees are White Oak (Quercus alba), Black Oak (Q. velutina), Hackberry (Celtis occidentalis), and several species of Hickory (Carya). Forest margins frequently contain Shingle Oak (Quercus imbricaria) and Honey Locust (Gleditsia triacanthos). Flowering peaks for the herbaceous flora of the upland forest occur in spring and late summer. Among the spring-flowering plants, Spring Beauty (Claytonia virginica), Dutchman's Breeches (Dicentra cucullaria), Dogtooth Violet (Erythronium albidum), Bluebell (Mertensia virginica), and several species of Trillium (Trillium), Violet (Viola), and Buttercup (Ranunculus) are notable. Late summer is the main flowering season for many members of the sunflower family.

Formerly pastured and farmed areas of the park now harbor a succession-type vegetation with Smooth Sumac (Rhus glabra), Hawthorn (Crataegus spp.), Sassafras (Sassafras albidum), and Hedge-Apple (Maclura pomifera), and a rich herbaceous flora. Roadsides and areas of recently disturbed ground are dominated by ruderal plants. Many of them are troublesome weeds, some native, such as Pigweeds (Amaranthus spp.), Ragweeds (Ambrosia spp.), and Fleabanes (Erigeron spp.), but most introduced. Examples of the latter are Lamb's Quarter (Chenopodium album), Canada Thistle (Cirsium arvense), Dandelion (Taraxacum officinale), Giant Foxtail (Setaria faberii), and Indian Mallow (Abutilon theophrasti).

On the southside of Robert Allerton Park an attempt is being made to reclaim a large area as prairie. In order to have a somewhat wider array of prairie species, we also sampled a stretch of the Illinois Central Railroad right-of-way north of Allerton Park. The prairie areas are particularly interesting in late summer and fall when many of the species are in flower. Among the dominant grasses are Big Bluestem (Andropogon furcatus), Indian Grass (Sorghastrum nutans), and Switch Grass (Panicum virgatum). Forbs found in the prairie vegetation include Wild Indigo (Baptisia leucantha), Wild Bergamot (Monarda fistulosa), and several species of Silphium (Silphium spp.), Goldenrod (Solidago spp.), and Tick-clover (Desmodium spp.).

The gardens, picnic grounds, and the experimental forest plots contain some cultivated native and exotic ornamental species. As public interest in the plantings is extensive, cultivars are included in the checklist, as far as they have been collected and are documented by herbarium vouchers.

The collection of most of the plants and the original compilation of a checklist was the work of the late Professor G. Neville Jones. The current revision was undertaken as part of the Springer-Sangamon Environmental Research Program (Bell, 1972; Jones and Bell, 1974) to facilitate biological research projects utilizing Robert Allerton Park and adjacent areas.

The checklist records a total of 857 species of vascular plants, representing 447 genera and 114 families. For the most part, Flora of Illinois, Ed. 3 (Jones, 1963), was followed for identification and nomenclature, although other floristic works were consulted also, e.g., Rehder (1940), Bailey (1949), Gleason and Cronquist (1963). The families have been listed in alphabetic order within major groups to facilitate the findings of names. Under Ferns and Fern Allies, 13 species are listed in three families, under Gymnosperms 21 species in five families, and under Angiosperms 823 species in 106 families. The 16 monocotyledonous families, representing 190 species, are marked with (M). There are 90 families of dicotyledons represented in Robert Allerton Park, with 633 species. Trees number 84 species, of which 19 are gymnosperms. In addition, there are 94 species of shrubs and woody vines. Of the 666 herbs listed, about 200 are annuals or biennials, the remainder perennials. Cultivated plants comprise 150 species. Of the approximately 700 species of vascular plants occurring spontaneously in the study area, about 130 are introduced. A few of the cultivated plants have escaped and are successfully maintaining themselves. Some of the native ferns were also probably originally planted in the park. The checklist of vascular plants has been annotated by indicating the cultivars and introduced plants. The voucher collection is on deposit in the herbarium of the University of Illinois (ILL).

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FERNS AND FERN ALLIES

Equisetaceae

Equisetum arvense L.
Equisetum hyemale L.
Equisetum laevigatum A.Br.

Ophioglossaceae

Botrychium obliquum Muhl.
Botrychium virginianum (L.) Sw.

Polypodiaceae

Adiantum pedatum L.
Asplenium platyneuron (L.) Oakes
Athyrium angustum (Willd.) Presl
Cystopteris protrusa (Weath.) Blasd.
Dryopteris intermedia (Muhl.) A.Gray
Dryopteris thelypteris (L.) A.Gray
Onoclea sensibilis L.
Polystichum acrostichoides (Michx.) Schott

GYMNOSPERMS

Cupressaceae

Chamaecyparis pisifera var. plumosa Beissn. cult.
Juniperus communis L. cult.
Juniperus virginiana L.
Thuja occidentalis L. cult.
Thuja orientalis L. cult.

Ginkgoaceae

Ginkgo biloba L. cult.

Pinaceae

Abies concolor (Gord. & Glend.) Lindl. cult.
Larix decidua Mill. cult.
Picea abies (L.) Karst. cult.
Picea glauca (Moench) Voss cult.
Pinus banksiana Lamb. cult.
Pinus resinosa Ait. cult.
Pinus rigida Mill. cult.
Pinus strobus L. cult.
Pinus sylvestris L. cult.
Pinus virginiana Mill. cult.
Pseudotsuga taxifolia Britt. cult.
Tsuga canadensis (L.) Carr. cult.

Taxaceae

Taxus cuspidata Sieb. & Zucc. cult.

Taxodiaceae

Metasequoia glyptostroboides Cheng & Hu. cult.

Taxodium distichum (L.) Rich. cult.

ANGISPERMS

Acanthaceae

Ruellia humilis Nutt.
Ruellia strepens L.

Aceraceae

Acer negundo L.
Acer rubrum L. cult.
Acer saccharinum L.
Acer saccharum Marsh.

Aizoaceae

Mollugo verticillata L.

Alismaceae (M)

Alisma subcordatum Raf.
Echinodorus rostratus Engelm.
Sagittaria latifolia Willd.

Amaranthaceae

Acnida altissima Riddell
Acnida subnuda (S.Wats.) Standl.
Acnida tamariscina (Nutt.) Wood
Amaranthus albus L.
Amaranthus graecizans L.
Amaranthus hybridus L.
Amaranthus retroflexus L.
Celosia argentea L. cult.
Froelichia gracilis (Hook.) Moq.

Amaryllidaceae (M)

Galanthus nivale L. cult.
Hypoxis hirsuta (L.) Cov.
Lycoris squamigera Maxim. cult.

Narcissus incomparibilis Mill. cult.
Narcissus poeticus L. cult.
Narcissus pseudonarcissus L. cult.

Anacardiaceae

Rhus glabra L.
Rhus radicans L.

Annonaceae

Asimina triloba (L.) Dunal

Apocynaceae

Apocynum androsaemifolium L.
Apocynum cannabinum L.
Apocynum pubescens R.Br.
Apocynum sibiricum Jacq.
Vinca minor L. cult. & escaped
Vinca rosea L. cult.

Araceae (M)

Arisaema dracontium (L.) Schott
Arisaema triphyllum (L.) Schott

Araliaceae

Aralia racemosa L.
Hedera helix L. cult.
Panax quinquefolius L.

Aristolochiaceae

Aristolochia serpentaria L.
Asarum canadense L.

Asclepiadaceae

Ampelamus albidum (Nutt.) Britt.
Asclepias amplexicaulis Sm.
Asclepias exaltata L.
Asclepias incarnata L.
Asclepias syriaca L.
Asclepias verticillata L.

Balsaminaceae

Impatiens biflora Walt.
Impatiens pallida Nutt.
Impatiens sultanii Hook. f. cult.

Berberidaceae

Berberis thunbergii DC. cult. & escaped
Caulophyllum thalictroides (L.) Michx.
Podophyllum peltatum L.

Betulaceae

Corylus americana Walt.
Ostrya virginiana (Mill.) K.Koch

Bignoniaceae

Campsis radicans (L.) Seem.
Catalpa bignonioides Walt. cult.

Boraginaceae

Borago officinalis L. cult.
Cynoglossum officinale L. introd.
Hackelia virginiana (L.) I.M.Johnston
Lithospermum arvense L. introd.
Lithospermum canescens (Michx.) Lehm.
Lithospermum latifolium Michx.
Mertensia virginica (L.) Pers.
Myosotis scorpioides L.
Myosotis verna Nutt.

Buxaceae

Buxus microphylla Sieb. & Zucc. cult.
Pachysandra terminalis Sieb. & Zucc. cult.

Callitrichaceae

Callitriche terrestris Raf.

Campanulaceae

Campanula americana L.
Campanula rapunculoides L. introd.
Specularia perfoliata (L.) A.DC.

Cannabinaceae

Cannabis sativa L. introd.
Humulus americanus Nutt.
Humulus japonicus Sieb. & Zucc. introd.

Capparidaceae

Cleome spinosa L. cult.
Polanisia dodecandra (L.) DC.

Caprifoliaceae

Diervilla lonicera Mill.
Lonicera bella Zab. cult.
Lonicera fragrantissima Carr. introd.
Lonicera japonica Thunb. cult. & escaped
Lonicera maackii Maxim. introd.
Lonicera morrowi A.Gray introd.
Lonicera prolifera (Kirchn.) Rehd.
Lonicera sempervirens L. introd.
Lonicera tatarica L. introd.
Sambucus canadensis L.
Symphoricarpos occidentalis Hook. cult.
Symphoricarpos orbiculatus Moench
Triosteum illinoense (Wieg.) Rydb.
Triosteum perfoliatum L.
Viburnum carlesii Hemsl. cult.
Viburnum lantana L. cult.
Viburnum opulus var. sterile DC. cult.
Viburnum prunifolium L.
Viburnum recognitum Fern. cult.
Viburnum trilobum Marsh.

Caryophyllaceae

Arenaria serpyllifolia L. introd.
Cerastium nutans. Raf.
Cerastium viscosum L. introd.
Cerastium vulgatum L. introd.
Dianthus armeria L. introd.
Dianthus deltoides L. introd.
Holosteum umbellatum L. introd.
Lychnis alba Mill. introd.
Saponaria officinalis L. introd.
Silene antirrhina L.
Silene stellata (L.) Ait. f.
Stellaria graminea L. introd.
Stellaria media (L.) Vill. introd.

Celastraceae

Celastrus orbiculatus Thunb. introd.
Celastrus scandens L.
Euonymus atropurpureus Jacq.
Euonymus fortunei var. radicans (Miq.) Rehd. cult.
Euonymus kiautschovicus Loes. cult.
Euonymus obovatus Nutt.

Chenopodiaceae

Chenopodium album L. introd.
Chenopodium ambrosioides L. introd.
Chenopodium boscianum Moq.
Kochia scoparia (L.) Schrad. introd.

Cistaceae

Helianthemum bicknellii Fern.

Commelinaceae (M)

Commelina communis L. introd.
Tradescantia virginiana L.

Compositae

Achillea millefolium L.
Ambrosia artemisiifolia L.
Ambrosia trifida L.
Antennaria neglecta Greene
Antennaria plantaginifolia (L.) Hook.
Anthemis cotula L. introd.
Arctium minus (L.) Bernh. introd.
Artemisia biennis L. introd.
Artemisia vulgaris L. cult.
Aster drummondii Lindl.
Aster ericoides L.
Aster lateriflorus (L.) Britt.
Aster novae-angliae L.
Aster ontarionis Wieg.
Aster pilosus Willd.
Aster praealtus Poir.
Aster sagittifolius Wedem.
Aster shortii Lindl.
Aster simplex Willd.
Aster simplex var. interior (Wieg.) Cronq.
Bidens aristosa (Michx.) Britt.
Bidens bipinnata L.
Bidens cernua L.
Bidens frondosa L.
Bidens tripartita L.
Bidens vulgata Greene
Chrysanthemum leucanthemum L. introd.
Chrysanthemum morifolium Ramat. cult.
Cichorium intybus L. introd.

Cirsium altissimum (L.) Spreng.
Cirsium arvense (L.) Scop. introd.
Cirsium discolor (Muhl.) Spreng.
Cirsium vulgare (Savi) Airy-Shaw introd.
Coreopsis tripteris L.
Eclipta alba (L.) Hassk.
Erechtites hieracifolia (L.) Raf.
Erigeron annuus (L.) Pers.
Erigeron canadensis L.
Erigeron philadelphicus L.
Erigeron strigosus Muhl.
Eupatorium altissimum L.
Eupatorium coelestinum L.
Eupatorium maculatum L.
Eupatorium perfoliatum L.
Eupatorium purpureum L.
Eupatorium rugosum Houtt.
Eupatorium serotinum Michx.
Eupatorium sessilifolium L.
Euthamia graminifolia (L.) Nutt.
Euthamia media Greene
Galinsoga ciliata (Raf.) Blake introd.
Gnaphalium obtusifolium L.
Gnaphalium purpureum L.
Helenium autumnale L.
Helianthus annuus L. cult. & escaped
Helianthus grosseserratus Martens
Helianthus hirsutus Raf.
Helianthus mollis Lam.
Helianthus strumosus L.
Helianthus tomentosus Michx.
Heliopsis helianthoides (L.) Sweet
Hieracium scabrum Michx.
Krigia biflora (Walt.) Blake
Kuhnia eupatorioides L.
Lactuca canadensis L.
Lactuca floridana (L.) Gaertn.
Lactuca saligna L. introd.
Lactuca scariola L. introd.
Lapsana communis L. introd.
Liatris aspera Michx.
Liatris pycnostachya Michx.
Matricaria matricarioides (Less.) Porter introd.
Parthenium integrifolium L.
Prenanthes aspera Michx.
Ratibida pinnata (Vent.) Barnh.
Rudbeckia hirta L.
Rudbeckia laciniata L.
Rudbeckia subtomentosa Pursh
Rudbeckia triloba L.
Senecio glabellus Poir.
Senecio plattensis Nutt.
Silphium integrifolium Michx.
Silphium laciniatum L.
Silphium perfoliatum L.
Silphium terebinthinaceum Jacq.
Solidago altissima L.
Solidago gigantea Ait.
Solidago glaberrima Martens
Solidago juncea Ait.
Solidago latifolia L.
Solidago nemoralis Ait.
Solidago patula Muhl.
Solidago rigida L.
Solidago speciosa Nutt.
Solidago ulmifolia Muhl.
Sonchus oleraceus L. introd.
Tagetes erecta L. cult.
Taraxacum officinale Wiggers introd.
Tragopogon dubius Scop. introd.
Tragopogon pratensis L. introd.
Verbesina alternifolia (L.) Britt.
Verbesina helianthoides Michx.
Vernonia fasciculata Michx.
Vernonia missurica Raf.
Xanthium strumarium L. introd.
Zinnia elegans Jacq. cult.

Convolvulaceae

Convolvulus americanus (Sims) Greene
Convolvulus arvensis L. introd.
Convolvulus spithamaeus L.
Cuscuta gronovii Willd.
Ipomoea hederacea Jacq. introd.
Ipomoea pandurata (L.) Meyer
Ipomoea purpurea (L.) Roth introd.
Ipomoea tricolor Cav. cult.

Cornaceae

Cornus drummondi C.A.Mey.
Cornus florida L.
Cornus obliqua Raf.
Cornus racemosa Lam.
Cornus stolonifera Michx.

Crassulaceae

Sedum spectabile Boreau cult.
Sedum sarmentosum Bunge cult.

Cruciferae

Alliaria petiolata (Bieb.) Cav. & Gr. introd.

Arabis glabra (L.) Bernh.
Arabis laevigata (Muhl.) Poir.
Arabis pycnocarpa Hopk.
Arabis shortii (Fern.) Gleason
Barbarea vulgaris R.Br. introd.
Brassica napus L. cult. & escaped
Brassica nigra (L.) Koch introd.
Capsella bursa-pastoris (L.) Medic. introd.
Cardamine bulbosa (Schreb.) BSP.
Cardamine douglassii (Torr.) Britt.
Cardamine pennsylvanica Muhl.
Dentari laciniata Muhl.
Descurainia brachycarpa (Richards.) O.E.Schulz
Draba verna L. introd.
Iodanthus pinnatifidus (Michx.) Steud.
Lepidium campestre (L.) R.Br. introd.
Lepidium densiflorum Schrad. introd.
Lepidium virginicum L.
Lobularia maritima (L.) Desv. cult.
Matthiola incana (L.) R.Br. cult.
Nasturtium officinale R.Br. introd.
Rorippa islandica (Oeder) Borbas
Sisymbrium officinale (L.) Scop. introd.

Cucurbitaceae

Citrullus vulgaris Schrad. cult. & escaped
Cucurbita pepo L. cult. & escaped
Sicyos angulatus L.

Cyperaceae (M)

Carex albolutescens Schw.
Carex artitecta Mack.
Carex blanda Dewey
Carex comosa Boott
Carex cristatella Britt.
Carex davisii Schw. & Torr.
Carex frankii Kunth
Carex granularis Muhl.
Carex gravida Bailey
Carex grayi Carey
Carex grisea Wahl.
Carex hirsutella Mack.
Carex hirtifolia Mack.
Carex hystricina Muhl.
Carex lacustris Willd.
Carex lanuginosa Michx.
Carex leavenworthii Dewey
Carex lupuliformis Sartw.
Carex lupulina Muhl.
Carex muskingumensis Schw.
Carex normalis Mack.
Carex pensylvanica Lam.
Carex rosea Schk.
Carex shortiana Dewey
Carex sparganioides Muhl.
Carex stricta Lam.
Carex tribuloides Wahl.
Carex trichocarpa Muhl.
Carex vulpinoidea Michx.
Cyperus acuminatus Torr. & Hook.
Cyperus diandrus Torr.
Cyperus ferruginescens Boeck.
Cyperus strigosus L.
Dulichium arundinaceum (L.) Britt.
Eleocharis acicularis (L.) R. & S.
Eleocharis compressa Sulliv.
Eleocharis obtusa (Willd.) Schultes
Eleocharis palustris (L.) R. & S.
Scirpus atrovirens Willd.
Scirpus fluviatilis (Torr.) A.Gray
Scirpus lineatus Michx.
Scirpus validus Vahl

Dioscoreaceae (M)

Dioscorea batatas Decne cult.
Dioscorea villosa L.

Ebenaceae

Diospyros virginiana L.

Ericaceae

Monotropa lanuginosa Michx.
Monotropa uniflora L.

Euphorbiaceae

Acalypha ostryaefolia Riddell
Acalypha rhomboidea Raf.
Acalypha virginica L.
Chamaesyce maculata (L.) Small
Chamaesyce supina (Raf.) Moldenke
Euphorbia corollata L.
Euphorbia cyparissias L. cult. & escaped
Euphorbia esula L. introd.
Poinsettia dentata (Michx.) Small
Ricinus communis L. cult.

Fagaceae

Quercus alba L.
Quercus bicolor Willd.
Quercus imbricaria Michx.
Quercus macrocarpa Michx.
Quercus palustris Muenchh. cult.
Quercus rubra L.
Quercus velutina Lam.

Fumariaceae

Dicentra cucullaria (L.) Bernh.

Geraniaceae

Geranium carolinianum L.
Geranium maculatum L.
Geranium pusillum Burm. f. introd.

Gramineae (M)

Agropyron repens (L.) Beauv. introd.
Agrostis alba L.
Agrostis hyemalis (Walt.) BSP.
Agrostis perennans (Walt.) Tuckerm.
Aira caryophyllea L.
Alopecurus carolinianus Walt.
Andropogon furcatus Muhl.
Andropogon scoparius Michx.
Andropogon virginicus L.
Aristida oligantha Michx.
Avena sativa L. cult. & escaped
Brachyelytrum erectum (Schreb.) Beauv.
Bromus commutatus Schrad. introd.
Bromus inermis Leyss. introd.
Bromus japonicus Thunb. introd.
Bromus purgans L.
Bromus secalinus L. introd.
Bromus tectorum L. introd.
Calamagrostis canadensis (Michx.) Beauv.
Cinna arundinacea L.
Dactylis glomerata L. introd.
Danthonia spicata (L.) Beauv.
Diarrhena americana Beauv.
Digitaria ischaemum (Schreb.) Muhl. introd.
Digitaria sanguinalis (L.) Scop. introd.
Echinochloa crusgalli (L.) Beauv. introd.
Eleusine indica (L.) Gaertn. introd.
Elymus canadensis L.
Elymus villosus Muhl.
Elymus virginicus L.
Eragrostis cilianensis (All.) Lut. introd.
Eragrostis frankii C.A.Mey.
Eragrostis hypnoides (Lam.) BSP.
Eragrostis pectinacea (Michx.) Nees
Eragrostis spectabilis (Pursh) Steud.
Festuca elatior L. introd.
Festuca obtusa Biehler
Festuca ovina L. introd.
Glyceria septentrionalis Hitchc.
Glyceria striata (Lam.) Hitchc.
Hordeum jubatum L. introd.
Hordeum pusillum Nutt.
Hystrix patula Moench
Leersia lenticularis Michx.
Leersia oryzoides (L.) Sw.
Leersia virginica Willd.
Lolium perenne L.
Miscanthus sinensis Anderss. cult.
Muhlenbergia frondosa (Poir.) Fern.
Muhlenbergia schreberi J.F.Gmel.
Muhlenbergia sobolifera (Muhl.) Trin.
Muhlenbergia tenuiflora (Willd.) BSP.
Panicum capillare L.
Panicum clandestinum L.
Panicum dichotomiflorum Michx.
Panicum huachucae Ashe
Panicum latifolium L.
Panicum scribnerianum Nash
Panicum virgatum L.
Paspalum circulare Nash
Paspalum pubescens Muhl.
Phalaris arundinacea L.
Phleum pratense L. introd.
Poa annua L. introd.
Poa compressa L. introd.
Poa pratensis L. introd.
Poa sylvestris Gray
Secale cereale L. cult. & escaped
Setaria faberii Herm. introd.
Setaria lutescens (Weigel) F.T.Hubb introd.
Setaria viridis (L.) Beauv. introd.
Sorghastrum nutans (L.) Nash
Spartina pectinata Link
Sphenopholis intermedia Rydb.
Sporobolus asper (Michx.) Kunth
Stipa spartea Trin.
Tridens flavus (L.) Hitchc.
Triticum aestivum L. cult. & escaped
Zea mays L. cult.

Grossulariaceae

Ribes alpinum L. cult.
Ribes americanum Mill.
Ribes missouriense Nutt.

Hamamelidaceae

Liquidambar styraciflua L. cult.

Hydrangeaceae

Hydrangea quercifolia Bartr. cult.
Philadelphus pubescens Loisel. cult.

Hydrocharitaceae (M)

Elodea occidentalis (Pursh) St. John

Hydrophyllaceae

Ellisia nyctelea L.
Hydrophyllum appendiculatum Michx.
Hydrophyllum virginianum L.

Hypericaceae

Hypericum perforatum L. introd.
Hypericum punctatum Lam.
Hypericum sphaerocarpum Michx.

Illecebraceae

Paronychia canadensis (L.) Wood

Iridaceae (M)

Crocus maesiacus Ker cult.
Iris germanica L. cult.
Iris shrevei Small
Sisyrinchium albidum Raf.
Sisyrinchium angustifolium Mill.
Sisyrinchium campestre Bickn.

Juglandaceae

Carya cordiformis (Wang.) K.Koch
Carya laciniosa (Michx. f.) Loud.
Carya ovalis (Wang.) Sarg.
Carya ovata (Mill.) K.Koch
Carya texana Buckl.
Carya tomentosa Nutt.
Juglans nigra L.

Juncaceae (M)

Juncus tenuis Willd.
Juncus torreyi Cov.

Labiatae

Agastache nepetoides (L.) Ktze.
Agastache scrophulariaefolia (Willd.) Ktze.
Blephilia hirsuta (Pursh) Benth.
Glecoma hederacea L. introd.
Hedeoma pulegioides (L.) Pers.
Lamium amplexicaule L. introd.
Leonurus cardiaca L. introd.
Lycopus americanus Muhl.
Lycopus virginicus L.
Marrubium vulgare L. introd.
Mentha canadensis L.
Mentha gentilis L. cult.
Mentha piperita L. introd.
Molucella laevis L. cult.
Monarda fistulosa L.
Nepeta cataria L. introd.
Physostegia speciosa Sweet
Prunella vulgaris L. introd.
Pycnanthemum flexuosum (Walt.) BSP.
Pycnanthemum pilosum Nutt.
Pycnanthemum virginianum (L.) Dur. & Jacks.
Salvia farinacea Benth. cult.
Salvia pitcheri Torr.
Salvia pratensis L. cult. & escaped
Scutellaria lateriflora L.
Stachys arenicola Britt.
Stachys hispida Pursh
Stachys tenuifolia Willd.
Teucrium canadense L.

Lauraceae

Lindera benzoin (L.) Blume
Sassafras albidum (Nutt.) Nees

Leguminosae

Amorpha fruticosa L.
Amphicarpa bracteata (L.) Fern.
Amphicarpa comosa (L.) G.Don
Apios americana Medic.
Astragalus canadensis L.
Baptisia leucantha T. & G.
Cassia fasciculata Michx.

Cassia marilandica L.
Cercis canadensis L.
Desmodium canadense (L.) DC.
Desmodium glutinosum (Muhl.) Wood
Desmodium illinoense A.Gray
Desmodium longifolium (T. & G.) Smyth
Desmodium paniculatum (L.) DC.
Gleditsia triacanthos L.
Glycine max (L.) Merr. cult.
Gymnocladus dioica (L.) K.Koch
Lathyrus latifolius L. cult. & escaped
Lespedeza bicolor Turcz. introd.
Lespedeza capitata Michx.
Lespedeza cuneata (Dum.-Cours.) G.Don introd.
Lespedeza stipulacea Maxim. introd.
Lespedeza violacea (L.) Pers.
Medicago lupulina L. introd.
Medicago sativa L. cult. & escaped
Melilotus alba Desr. introd.
Melilotus officinalis (L.) Lam. introd.
Petalostemum purpureum (Vent.) Rydb.
Robinia pesudoacacia L. introd.
Strophostyles helvola (L.) Britt.
Trifolium dubium Sibth. introd.
Trifolium hybridum L. introd.
Trifolium pratense L. introd.
Trifolium procumbens L. introd.
Trifolium repens L. introd.
Wisteria floribunda (Willd.) DC. cult.
Wisteria macrostachya Nutt. cult.

Lemnaceae (M)

Lemna minor L.

Liliaceae (M)

Allium canadense L.
Allium cepa L. cult.
Allium tricoccum Ait.
Allium vineale L. introd.
Asparagus officinalis L. cult. & escaped
Camassia scilloides (Raf.) Cory
Colchicum autumnale L. cult.
Convallaria majalis L. cult.
Erythronium albidum Nutt.
Fritillaria meleagris L. cult.
Hemerocallis flava L. cult.
Hemerocallis fulva L. cult. & escaped
Hyacinthus orientalis L. cult.
Lilium henryi Baker cult.
Lilium michiganense Farw.
Lilium tigrinum Ker cult.
Muscari armeniacum Leicht. cult.
Nothoscordum bivalve (L.) Britt.
Polygonatum biflorum (Walt.) Ell.
Polygonatum commutatum (Schult.) Dietr.
Scilla bifolia L. cult.
Scilla nonscripta (L.) Hoffmgg. & Link cult.
Smilacina racemosa (L.) Desf.
Smilacina stellata (L.) Desf.
Smilax hispida Muhl.
Smilax lasioneura Hook.
Trillium grandiflorum (Michx.) Salisb.
Trillium nivale Riddell
Trillium recurvatum Beck
Tulipa gesneriana L. cult.
Uvularia grandiflora Sm.
Yucca filamentosa L. cult. & escaped

Lobeliaceae

Lobelia cardinalis L.
Lobelia inflata L.
Lobelia siphilitica L.

Lythraceae

Ammannia coccinea Rottb.

Magnoliaceae

Liriodendron tulipifera L. cult.

Malvaceae

Abutilon theophrasti Medic. introd.
Althaea rosea Cav. cult. & escaped
Hibiscus militaris Cav.
Hibiscus trionum L. introd.
Malva rotundifolia L. introd.
Malva neglecta Wallr. introd.
Sida spinosa L.

Menispermaceae

Menispermum canadense L.

Moraceae

Maclura pomifera (Raf.) Schneid. cult. & escaped
Morus alba L. introd.
Morus rubra L.
Morus tatarica L. introd.

Nyctaginaceae

Mirabilis nyctaginea (Michx.) MacM.

Nymphaeaceae

Nymphaea tuberosa Paine cult.

Oleaceae

Chionanthus virginica L. cult.
Forsythia suspensa (Thunb.) Vahl cult.
Fraxinus americana L.
Fraxinus lanceolata Berkh.
Fraxinus pennsylvanica Marsh.
Fraxinus quadrangulata Michx.
Ligustrum obtusifolium Sieb. & Zucc. cult. & escaped
Ligustrum vulgare L. cult.
Syringa vulgaris L. cult.

Onagraceae

Circaea latifolia Hill
Epilobium coloratum Muhl.
Gaura biennis L.
Ludwigia alternifolia L.
Oenothera biennis L.

Orchidaceae (M)

Aplectrum hyemale (Muhl.) Torr.
Corallorhiza odontorhiza (Willd.) Nutt.
Cypripedium calceolus L. var. pubescens (Willd.) Correll
Liparis lilifolia (L.) Rich.
Orchis spectabilis L.
Spiranthes cernua (L.) Rich.
Spiranthes ovalis Lindl.

Orobanchaceae

Orobanche uniflora L.

Oxalidaceae

Oxalis corniculata L. introd.
Oxalis dillenii Jacq.
Oxalis stricta L.
Oxalis violacea L.

Paeoniaceae

Paeonia lactiflora Pall. cult.

Papaveraceae

Papaver orientale L. cult.
Sanguinaria canadensis L.

Penthoraceae

Penthorum sedoides L.

Phrymaceae

Phryma leptostachya L.

Phytolaccaceae

Phytolacca americana L.

Plantaginaceae

Plantago aristata Michx.
Plantago lanceolata L. introd.
Plantago major L. introd.
Plantago rugelii Dec.
Plantago virginica L.

Platanaceae

Platanus occidentalis L.

Polemoniaceae

Phlox divaricata L.
Phlox drummondii Hook. cult.
Phlox glaberrima L.
Phlox maculata L.
Phlox paniculata L. cult.
Phlox pilosa L.
Phlox subulata L. cult.

Polygalaceae

Polygala sanguinea L.

Polygala verticillata L.

Polygonaceae

Polygonum aviculare L. introd.
Polygonum hydropiperoides Michx.
Polygonum lapathifolium L. introd.
Polygonum pennsylvanicum L.
Polygonum persicaria L. introd.
Polygonum punctatum L.
Polygonum sagittatum L.
Polygonum scandens L.
Polygonum virginianum L.
Rheum raponticum L. cult.
Rumex acetosella L. introd.
Rumex altissimus Wood
Rumex crispus L. introd.
Rumex obtusifolius L. introd.

Portulacaceae

Claytonia virginica L.
Portulaca oleracea L. introd.

Potamogetonaceae (M)

Potamogeton crispus L.
Potamogeton foliosus Raf.
Potamogeton pectinatus L.

Primulaceae

Dodecatheon meadia L.
Lysimachia ciliata L.
Lysimachia lanceolata Walt..
Lysimachia nummularia L. introd.
Samolus parviflorus Raf.

Ranunculaceae

Aconitum carmichaelii Debx. cult.
Actaea alba (L.) Mill.
Anemone canadensis L.
Anemone virginiana A.Gray
Anemonella thalictroides (L.) Spach
Aquilegia canadensis L.
Aquilegia chrysantha A.Gray cult.
Aquilegia glandulosa Fisch. cult.
Caltha palustris L.
Clematis dioscoreifolia Levl. & Van cult. & escaped
Clematis pitcheri T. & G.
Delphinium ajacis L. cult. & escaped
Delphinium cheilanthum var. formosum Huth cult.
Eranthis hyemalis (L.) Salisb. cult.
Hepatica acutiloba DC.
Isopyrum biternatum (Raf.) T. & G.
Myosurus minimus L. introd.
Ranunculus abortivus L.
Ranunculus fascicularis Muhl.
Ranunculus flabellaris Raf.
Ranunculus recurvatus Poir.
Ranunculus septentrionalis Poir.
Thalictrum dioicum L.
Thalictrum revolutum DC.

Rhamnaceae

Ceanothus americanus L.
Rhamnus frangula L. cult.
Rhamnus lanceolata Pursh

Rosaceae

Agrimonia gryposepala Wallr.
Agrimonia parviflora Ait.
Agrimonia pubescens Wallr.
Amelanchier arborea (Michx. f.) Fern.
Aronia arbutifolia Ell. cult.
Chaenomeles lagenaria (L.) Koidz. cult.
Crataegus calpodendron (Ehrh.) Medic.
Crataegus crusgalli L.
Crataegus margaretta Ashe
Crataegus mollis (T. & G.) Scheele
Exochorda racemosa (Lindl.) Rehd. cult.
Fragaria virginiana Duch.
Geum canadense Jacq.
Geum laciniatum Murray
Geum vernum (Raf.) T. & G.
Gillenia stipulata (Muhl.) Trel.
Malus floribunda Sieb. cult.
Malus ioensis (Wood) Britt.
Malus pumila Mill. cult. & escaped
Physocarpus opulifolius (L.) Maxim. cult.
Potentilla arguta Pursh
Potentilla monspeliensis L.
Potentilla recta L. introd.
Potentilla simplex Michx.
Prunus americana Marsh.
Prunus armeniaca L. cult.
Prunus hortulana Bailey
Prunus lanata (Sudw.) Mack. & Bush
Prunus persica (L.) Batsch cult.

Prunus serotina Ehrh.
Pyrus communis L. cult.
Rhodotypos tetrapetala Mak. cult.
Rosa blanda Ait. cult.
Rosa canina L. cult.
Rosa carolina L.
Rosa chinensis Jacq. cult.
Rosa cinnamomea L. cult.
Rosa gallica L. cult.
Rosa multiflora Thunb. cult. & escaped
Rosa rugosa Thunb. cult.
Rosa setigera Michx.
Rosa xanthina Lindl. cult.
Rubus allegheniensis Porter
Rubus canadensis L. introd.
Rubus flagellaris Willd.
Rubus occidentalis L.
Rubus ostryifolius Rydb.
Spiraea prunifolia Sieb. & Zucc. cult.

Rubiaceae

Cephalanthus occidentalis L.
Diodia teres Walt.
Galium aparine L.
Galium circaezans Michx.
Galium concinnum T. & G.
Galium obtusum Bigel.
Galium triflorum Michx.
Houstonia lanceolata (Poir.) Britt.

Rutaceae

Ptelea trifoliata L.
Zanthoxylum americanum Mill.

Salicaceae

Populus alba L. cult.
Populus deltoides Marsh.
Populus nigra var. italica Muench. cult.
Populus tremuloides Michx. cult.
Salix alba L. cult.
Salix babylonica L. cult.
Salix discolor Muhl.
Salix eriocephala Michx.
Salix fragilis L. cult.
Salix interior Rowlee
Salix nigra Marsh.
Salix purpurea L. cult.

Saururaceae

Saururus cernuus L.

Saxifragaceae

Heuchera richardsonii R.Br.

Scrophulariaceae

Antirrhinum majus L. cult.
Aureolaria grandiflora (Benth.) Pennell
Chaenorrhinum minus (L.) Lange introd.
Chelone glabra L.
Collinsia verna Nutt.
Cymbalaria muralis Gaertn. cult.
Dasistoma macrophylla (Nutt.) Raf.
Gerardia tenuifolia Vahl
Gratiola neglecta Torr.
Leucospora multifida (Michx.) Nutt.
Linaria vulgaris L. introd.
Lindernia dubia (L.) Pennell
Mimulus ringens L.
Penstemon calycosus Small
Penstemon pallidus Small
Scrophularia marilandica L.
Verbascum blattaria L. introd.
Verbascum thapsus L. introd.
Veronica arvensis L. introd.
Veronica didyma Ten. introd.
Veronica peregrina L. introd.
Veronicastrum virginicum (L.) Farw.

Simarubaceae

Ailanthus altissima (Mill.) Swingle cult. & escaped

Solanaceae

Datura stramonium L. introd.
Lycopersicum esculentum Mill. cult. & escaped
Nicotiana affinis T.Moore cult.
Petunia hybrida Vilm. cult.
Physalis heterophylla Nees
Physalis subglabrata Mack. & Bush
Solanum carolinense L.
Solanum nigrum L.
Solanum rostratum Dunal

Staphyleaceae

Staphylea trifolia L.

Tiliaceae

Tilia americana L.
Tilia heterophylla Vent. cult.

Typhaceae (M)

Typha latifolia L.

Ulmaceae

Celtis occidentalis L.
Ulmus americana L.
Ulmus pumila L. introd.
Ulmus rubra Muhl.

Umbelliferae

Chaerophyllum procumbens (L.) Crantz
Cicuta maculata L.
Conium maculatum L. introd.
Cryptotaenia canadensis (L.) DC.
Daucus carota L. introd.
Eryngium yuccifolium Michx.
Heracleum lanatum Michx.
Osmorhiza claytoni (Michx.) Clarke
Osmorhiza longistylis (Torr.) DC.
Pastinaca sativa L. introd.
Perideridia americana (Nutt.) Reichenb.
Sanicula canadensis L.
Sanicula gregaria Bickn.
Sium suave Walt.
Taenidia integerrima (L.) Drude
Thaspium barbinode (Michx.) Nutt.
Torilis japonica (Houtt.) DC.
Zizia aurea (L.) Koch

Urticaceae

Boehmeria cylindrica (L.) Sw.
Laportea canadensis (L.) Gaudich
Parietaria pennsylvanica Muhl.
Pilea pumila (L.) A.Gray
Urtica gracilis Ait.

Verbenaceae

Phyla lanceolata (Michx.) Greene
Verbena bracteata Lag. & Rodr.
Verbena canadensis (L.) Britt. cult. & escaped
Verbena hastata L.
Verbena stricta Vent.
Verbena urticifolia L.
Verbena x illicita Moldenke

Violaceae

Viola cucullata Ait.
Viola eriocarpa Schw.
Viola missouriensis Greene
Viola papilionacea Pursh
Viola sororia Willd.
Viola striata Ait.

Vitaceae

Parthenocissus quinquefolia (L.) Planch.
Vitis aestivalis Michx.
Vitis cinerea Engelm.
Vitis labrusca Bailey cult.
Vitis riparia Michx.
Vitis vinifera L. cult.
Vitis vulpina L.

Zingiberaceae (M)

Hedychium coronaricum Koenig cult.

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AQUATIC MALACOSTRACA RECORDED FOR ILLINOIS, WITH NOTES ON THEIR DISTRIBUTIONS AND HABITATS WITHIN THE STATE

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Abstract.—Fifty-three species of aquatic Malacostraca have been recorded for Illinois, four erroneously. For each species are given citations to its occurrence in Illinois, a synonymy, its type-locality, and its range and habitat in Illinois.

The subclass Malacostraca includes the larger crustaceans which, except for the terrestrial isopods, are all aquatic. Illinois Malacostraca include sow bugs (Isopoda), scuds (Amphipoda), freshwater shrimps and crayfishes (Decapoda). The opposum shrimp, *Mysis relicta*, has apparently not been recorded from Illinois, although it is known from the deep waters of the Great Lakes including Lake Michigan (Smith 1874, Ricker 1959).

The following 53 species (including four erroneously recorded), including 13 isopods, 20 amphipods, and 20 decapods, are believed to comprise a complete list of the aquatic Malacostraca recorded for Illinois. Given for each species are a synonymy (alternative names used in the literature for the Illinois fauna), citations to its occurrence in the state, its type-locality, and a statement about its range and habitat in Illinois. Only those publications actually citing Illinois are listed.

This list should be useful to persons involved in the identification of aquatic organisms and the preparation of environmental impact statements in Illinois. A permanent collection of Malacostraca is maintained at the Illinois Natural History Survey, and donations of specimens to the Survey will be greatly appreciated.

Thirteen species of aquatic Malacostraca were originally described from specimens collected in Illinois. Three species were described from Union County: *Asellus brevicauda* Forbes 1876, *Asellus intermedius* Forbes 1876, and *Orconectes illinoiensis* Brown 1956, three from Monroe County: *Asellus packardi* (Mackin and Hubricht 1940), *Gammarus acherondytes* Hubricht and Mackin 1940, and *Gammarus troglophilus* Hubricht and Mackin 1940, two from McLean County: *Bactrurus mucronatus* (Forbes 1876) and *Procambarus gracilis* (Bundy 1876), and one each from Champaign County: *Asellus kendeighi* Steeves and Seidenberg 1971, St. Clair County: *Asellus spatulata* (Mackin and Hubricht 1940), Knox County: *Apocrangonyx lucifugus* (Hay 1882), Jackson County: *Apocrangonyx subtilis* Hubricht 1943, and Marshall County: *Orconectes immunis* (Hagen 1870).

ORDER ISOPODA

FAMILY ASELLIDAE

Asellus brevicauda Forbes 1876

Asellus brevicauda Forbes 1876, Underwood 1886, Richardson 1900, Van Name 1936, 1940, Nicholas 1960.

Asellus brevicaudus: Mackin and Hubricht 1938.

Asellus brevicauda brevicauda: Williams 1970, 1972.

Originally described from "clear, rocky rills in Jackson and Union counties in Southern Illinois" (Forbes 1876), the type-locality of *Asellus brevicauda* was restricted to Union County, Illinois, by Williams (1970). Known in Illinois with certainty only from Union, Monroe, and St. Clair counties (Williams 1970).

Asellus communis Say 1818

Asellus communis: Hay 1882, Underwood 1886, Richardson 1900, Mackin and Hubricht 1938, Van Name 1940.

Asellus communis is a species of the eastern United States (Williams 1970) erroneously reported from Illinois by Hay in 1882 and by several subsequent investigators.

Asellus forbesi Williams 1970

Asellus forbesi: Hubert and Krull 1973.

Recently described from Culpeper County, Virginia, *Asellus forbesi* has been recorded in Illinois only from a flooded bottomland in Jackson County.

Asellus intermedius Forbes 1876

Asellus intermedius Forbes 1876, Hay 1878, Underwood 1886, Richardson 1900, Van Name 1936, Williams 1970, 1972.

Originally described from "the hill-country of southern Illinois, under stones in small streams" (Forbes 1876), Williams (1970) restricted the type-locality of *Asellus intermedius* to Callahan Creek, Cobden, Union County, Illinois. The species is widely distributed in Illinois (Williams 1970).

Asellus kendeighi Steeves and Seidenberg 1971

Asellus kendeighi Steeves and Seidenberg 1971.

Asellus kendeighi is known at present only from the type-locality, a drainage ditch with a subterranean source three miles north of Mayview, Champaign County, Illinois.

Asellus packardi (Mackin and Hubricht 1940)

Caecidotea packardi Mackin and Hubricht 1940, Van Name 1942, Nicholas 1960.

Originally described from Monroe County, Illinois, *Asellus packardi* is recorded in Illinois only from cave streams in Monroe and St. Clair counties.

Asellus spatulata (Mackin and Hubricht 1940)

Caecidotea spatulata Mackin and Hubricht 1940, Van Name 1942, Nicholas 1960.

Asellus spatulata is known in Illinois only from temporary pools at the type-locality in St. Clair County.

Asellus stygius (Packard 1871)

Asellus stygius: Forbes 1876, Underwood 1886, Steeves 1963.
Caecidotea stygia: Richardson 1900, Van Name 1936, Nicholas 1960.

Originally described as *Caecidotea stygia* from Mammoth Cave, Edmonson County, Kentucky, *Asellus stygius* is known in Illinois with certainty only from subterranean waters in Monroe County (Steeves 1963) although depicted by Steeves (1966) as occurring across southcentral Illinois.

Asellus tridentatus (Hungerford 1922)

Asellus tridentatus: Dexter 1954.

Originally described from a cistern in Lawrence, Kansas, *Asellus tridentatus* is a subterranean species recorded in Illinois only from a headwater drainage stream in Champaign County.

Lirceus fontinalis Rafinesque 1820

Mancasellus macrourus: Van Name 1940.
Lirceus fontinalis: Hubricht and Mackin 1949, Williams 1972, Hubert and Krull 1973.

Originally described from springs and small streams near Lexington, Kentucky, *Lirceus fontinalis* has been recorded in Illinois with certainty only from Champaign, Clark, and Johnson counties.

Lirceus garmani Hubricht and Mackin 1949

Lirceus garmani: Dexter 1954.

Lirceus garmani was described from Cedar County, Missouri, and is recorded in Illinois only from a headwater stream in Champaign County.

Lirceus lineatus (Say 1818)

Mancasellus danielsi: Van Name 1936.
Lirceus lineatus: Hubricht and Mackin 1949, Williams 1972.
Described as *Asellus lineatus* from swamps in South Carolina, *Lirceus lineatus* was recorded by Hubricht and Mackin (1949) from Fox Lake in Lake County, Illinois.

Lirceus louisianae (Mackin and Hubricht 1938)

Lirceus louisianae: Hubricht and Mackin 1949, Williams 1972.
Recorded in Illinois only from Union County, *Lirceus louisianae* was described originally from a small creek in Natchitoches Parish, Louisiana.

ORDER AMPHIPODA

FAMILY HAUSTORIIDAE

Pontoporeia affinis (Lindström 1855)

Pontoporeia hoyi: Forbes 1876.
Pontoporeia filicornis: Forbes 1876.
Pontoporeria: Eggleton 1936.
An inhabitant of deep, cold lakes and described originally from Europe, *Pontoporeia affinis* is probably restricted in Illinois to Lake Michigan (Forbes 1876, Pennak 1953).

FAMILY HYALELLIDAE

Hyalella azteca (Saussure 1858)

Hyalella dentata: Forbes 1876.
Allorchestes dentatus: Underwood 1886.
Hyalella knickerbockeri: Weckel 1907.
Hyalella azteca: Hubricht and Mackin 1940, Hubricht 1943.
Originally described from Veracruz, Mexico, *Hyalella azteca* is widespread in Illinois and found in a variety of aquatic habitats.

FAMILY TALITRIDAE

Talitrus alluaudi Chevreu 1896

Talitrus alluaudi: Hubricht and Mackin 1940.
An Old World species, *Talitrus alluaudi* has been recorded from greenhouses on the University of Illinois campus in Champaign County (Hubricht and Mackin 1940).

FAMILY GAMMARIDAE

Apocrangonyx lucifugus (Hay 1882)

Crangonyx lucifugus Hay 1882, Underwood 1886.
Apocrangonyx lucifugus: Nicholas 1960, Holsinger 1969, 1972.

Originally described from a well in Abingdon, Knox County, Illinois, *Apocrangonyx lucifugus* is known only from the type-locality.

Apocrangonyx subtilis Hubricht 1943

Apocrangonyx subtilis Hubricht 1943, Nicholas 1960, Holsinger 1969, 1972.

Distributed in Illinois in seeps and cave pools from Adams County south-southeastward to Union County (Holsinger 1972), *Apocrangonyx subtilis* was originally described from Jackson County, Illinois.

Bactrurus brachycaudus Hubricht and Mackin 1940

Bactrurus brachycaudus Hubricht and Mackin 1940, Hubricht 1943, Nicholas 1960, Holsinger 1972.

Originally described from St. Louis County, Missouri, *Bactrurus brachycaudus* is distributed in streams, seeps, and springs in southwestern Illinois (Holsinger 1972).

Bactrurus mucronatus (Forbes 1876)

Crangonyx mucronatus Forbes 1876, Underwood 1886.
Eucrangonyx mucronatus: Weckel 1907.
Bactrurus mucronatus: Hubricht 1943, Shoemaker 1945, Nicholas 1960, Holsinger 1972.

Bactrurus mucronatus was originally described from McLean County, Illinois, and is distributed in drains, wells, and caves in central, eastern, and southeastern Illinois (Holsinger 1972).

Crangonyx forbesi (Hubricht and Mackin 1940)

Eucrangonyx forbesi Hubricht and Mackin 1940.
Crangonyx forbesi: Hubricht 1943, Bousfield 1958, Nicholas 1960, Holsinger 1972, Hubert and Krull 1973.

Described originally from St. Louis County, Missouri, *Crangonyx forbesi* is found in springs, streams, and ponds in southwestern Illinois (Holsinger 1972).

Crangonyx gracilis Smith 1871

Crangonyx gracilis: Forbes 1876, Hay 1882, Underwood 1886.
Eucrangonyx gracilis: Weckel 1907, Hubricht and Mackin 1940.
Crangonyx gracilis gracilis: Hubricht 1943.

Originally described from Lake Superior, Ontario, *Crangonyx gracilis* has been reported from Illinois by numerous investigators; however, the systematics of this species are in doubt and the distribution in Illinois is uncertain.

Crangonyx minor Bousfield 1958

Crangonyx minor: Holsinger 1972.

Described from material collected in Oxford County, Ontario, *Crangonyx minor* is distributed in a variety of habitats in central, western, and southern Illinois (Holsinger 1972).

Crangonyx obliquus (Hubricht and Mackin 1940)

Crangonyx obliquus: Hubricht 1943, Bousfield 1958.

Originally described from Johnson County, Arkansas, and subsequently recorded from Illinois, the systematics of *Crangonyx obliguus* are badly in need of investigation and the distribution of this species in Illinois is unknown (Holsinger 1972).

Crangonyx packardi Smith 1888

Crangonyx gracilis packardi: Hubricht 1943.
Crangonyx packardi: Holsinger 1972.

Crangonyx packardi was originally described from Orange or Lawrence County, Indiana. Although the distribution is uncertain, this or a closely related subterranean species occurs in southern Illinois (Holsinger 1972).

Crangonyx pseudogracilis Bousfield 1958

Crangonyx pseudogracilis: Holsinger 1972.

Originally described from Lennox and Addington counties, Ontario, the distribution of *Crangonyx pseudogracilis* in Illinois is uncertain. The species is known at present from rivers, lakes, sloughs, and ponds in small areas of east-central and west-central Illinois (Holsinger 1972).

Crangonyx shoemakeri (Hubricht and Mackin 1940)

Crangonyx shoemakeri Hubricht and Mackin 1940, Hubricht 1943, Pennak 1953.

An East Coast species originally described from Washington, D.C., *Crangonyx shoemakeri* was erroneously reported from Illinois by several investigators.

Gammarus acherondytes Hubricht and Mackin 1940

Gammarus acherondytes Hubricht and Mackin 1940, Bousfield 1958, Nicholas 1960, Cole 1970a, 1970b, Holsinger 1972.

Described from Monroe County, Illinois, *Gammarus acherondytes* is at present known only from cave streams in Monroe and St. Clair counties, Illinois (Holsinger 1972).

Gammarus fasciatus Say 1818

Gammarus fasciatus: Forbes 1876, Weckel 1907, Holsinger 1972.

Thought to have been described from material collected in Pennsylvania, *Gammarus fasciatus* is distributed in streams in northwestern Illinois (Holsinger 1972). Although recorded by Forbes (1876) from areas in Illinois other than the northwest, these records were based on misidentifications.

Gammarus minus Say 1818

Gammarus minus: Cole 1970a, 1970b, Holsinger 1972.

Gammarus minus pinicollis Cole 1970b.

Originally described from Lancaster County, Pennsylvania, *Gammarus minus* is distributed in springs and streams in extreme western and southwestern Illinois (Holsinger 1972). Cole (1970b) described *G. m. pinicollis* from Elm Spring in the Pine Hills region of Union County, Illinois.

Gammarus pseudolimnaeus Bousfield 1958

Gammarus limnaeus: Hubricht and Mackin 1940, Hubricht 1943.

Gammarus pseudolimnaeus Bousfield 1958, Cole 1970a, 1970b, Holsinger 1972.

Widespread in streams and springs in northern, western, and southern Illinois, (Holsinger 1972), *Gammarus pseudolimnaeus* was described originally from Ottawa, Ontario.

Gammarus troglophilus Hubricht and Mackin 1940

Gammarus troglophilus Hubricht and Mackin 1940, Hubricht 1943, Bousfield 1958, Nicholas 1960, Cole 1970a, 1970b, Holsinger 1972.

Described from Monroe County, Illinois, *Gammarus troglophilus* is known from cave streams and springs in 10 counties in southwestern Illinois (Holsinger 1972).

Stygobromus iowae Hubricht 1943

Stygobromus iowae: Holsinger 1972.

Described from Fayette County, Iowa, *Stygobromus iowae* is known in Illinois only from a mine in Jo Daviess County (Holsinger 1972).

ORDER DECAPODA

FAMILY PALAEMONIDAE

Macrobrachium ohione (Smith 1874)

Palaemon ohionis: Forbes 1876, Underwood 1886.
M. ohionis: Creaser 1932.
Macrobrachium ohionis: McCormick 1934, Gunter 1937, Schmitt 1953.
Macrobrachium ohione: Hedgepeth 1949, Holthius 1952.

Originally described from the Ohio River at Cannelton, Indiana, *Macrobrachium ohione* is known in Illinois from the Mississippi and Ohio rivers.

Palaemonetes kadiakensis Rathburn 1902

Palaemonetes exilipes: Forbes 1876, Hay 1882, Creaser 1931, 1932.
Palaemonetes paludosa: Underwood 1886.
Palaemonetes kadiakensis: Holthius 1952.

According to Holthius (1949, 1952), the only species of *Palaemonetes* in the Midwest is *Palaemonetes kadiakensis*, and all references in the Illinois literature must refer to this species. Originally described from Kodiak Island, Alaska, *Palaemonetes kadiakensis* is found in sluggish water habitats throughout Illinois.

FAMILY ASTACIDAE

Cambarellus shufeldtii (Faxon 1884)

Cambarus shufeldtii: Faxon 1914.
Cambarellus shufeldtii: Brown 1955, Hobbs 1968, 1972, Hubert and Krull 1973.

Described from near New Orleans, Louisiana, *Cambarellus shufeldtii* is found in sluggish water habitats in extreme southern Illinois.

Procambarus acutus (Girard 1852)

Cambarus acutus: Hagen 1870, Smith 1874, Forbes 1876.
Cambarus stygius: Forbes 1876.
Cambarus blandingii acuta: Faxon 1885, Underwood 1886.
Cambarus blandingii acutus: Faxon 1890, 1914, Harris 1903, Creaser 1931, 1932.
Cambarus blandingii: Ortmann 1902.
Cambarus blandingi acutus: Rietz 1912, Ortmann 1931, Cralley 1932.
Procambarus blandingii acutus: Bovbjerg 1952, Brown 1955, 1959.
Procambarus acutus acutus: Hobbs 1972.
Procambarus blandingi: Hubert and Krull 1973.

Originally described from Kemper County, Mississippi, *Procambarus acutus* is common in sluggish water habitats throughout Illinois.

Cambarus stygius, described from a Lake Michigan specimen, has been considered by subsequent investigators to be a synonym of *Procambarus acutus*.

Procambarus clarkii (Girard 1852)

Procambarus clarkii: Brown 1955, 1959, Hobbs 1968, 1972.

Described from specimens collected "between San Antonio and El Paso del Norte, Texas," *Procambarus clarkii* is limited in Illinois to sluggish water habitats in the extreme southern part of the state.

Procambarus gracilis (Bundy 1876)

Cambarus gracilis: Forbes 1876, Underwood 1886, Faxon 1885, 1890, 1914, Ortmann 1902, 1905, Harris 1903, Rietz 1912, Cralley 1932, Creaser 1932, Bovbjerg 1952.

Procambarus gracilis: Brown 1955, Hobbs 1968, 1972.

Described originally from Normal, McLean County, Illinois, and Racine, Racine County, Wisconsin, *Procambarus gracilis* is a burrowing inhabitant of prairie habitats in Illinois and presumably occurs throughout the state except in unglaciated areas.

Procambarus troglodytes (Leconte 1856)

Cambarus troglodytes: Hagen 1870, Forbes 1876, Faxon 1885, Harris 1903, Rietz 1912.

Procambarus troglodytes is an Atlantic Coast species originally described from Georgia and was erroneously reported from Marshall County, Illinois, by Hagen (1870).

Orconectes illinoiensis Brown 1956

Orconectes illinoiensis: Brown 1955, 1956, Hobbs 1968, 1972.

Orconectes illinoisensis: Fitzpatrick 1967.

Described from Cypress Creek, Union County, Illinois, *Orconectes illinoiensis* is apparently endemic to streams in the hill regions of extreme southern Illinois.

Orconectes immunis (Hagen 1870)

Cambarus immunis Hagen 1870, Smith 1874, Forbes 1876, Faxon 1885, Underwood 1886, Ortmann 1902, 1905, Harris 1903, Rietz 1912, Faxon 1914, Creaser 1931, 1932, Cralley 1932.

Faxonius immunis immunis: Creaser 1933.

Orconectes immunis x pedianus: Bovbjerg 1952.

Orconectes immunis: Brown 1955, Hobbs 1968, 1972.

Common in sluggish habitats throughout Illinois, the type-locality of *Orconectes immunis* was designated as Lawn Ridge, Marshall County, Illinois, by Faxon (1914).

Orconectes indianensis (Hay 1896)

Cambarus indianensis: Rietz 1912, Ortmann 1931, Creaser 1932.
Orconectes indianensis: Brown 1955, Hobbs 1968, 1972.
Described from Gibson County, Indiana, *Orconectes indianensis* is restricted in Illinois to rocky streams in the southeastern portion of the state.

Orconectes kentuckiensis Rhoades 1944

Orconectes kentuckiensis: Brown 1955, Hobbs 1972.
Described from Crittenden County, Kentucky ,*Orconectes kentuckiensis* has a very small range and is limited in Illinois to rocky streams in Hardin County.

Orconectes lancifer (Hagen 1870)

Cambarus lancifer: Faxon 1914.
Orconectes lancifer: Brown 1955, Hobbs 1968, 1972.
A southern species described from Union County , Mississippi (Penn 1939), *Orconectes lancifer* is a rare sluggish water inhabitant of extreme southern Illinois.

Orconectes propinquus (Girard 1852)

Cambarus propinquus: Hagen 1870, Forbes 1876, Faxon 1885, Underwood 1886, Harris 1903, Ortmann 1905, 1931, Rietz 1912, Faxon 1914, Jewell 1920, Creaser 1931, 1932, Cralley 1932, Van Deventer 1937.
Orconectes propinquus propinquus: Bovbjerg 1952.
Orconectes propinquus: Brown 1955, Fitzpatrick 1967, Hobbs 1968, 1972.
Originally described from New York, *Orconectes propinquus* is found in rocky streams in eastern and northern Illinois.

Orconectes rusticus (Girard 1852)

Cambarus placidus Hagen 1870, Smith 1874, Forbes 1876.
Cambarus wisconsinensis: Forbes 1876, Rietz 1912.
Cambarus rusticus: Faxon 1885, Underwood 1886, Harris 1903, Ortmann 1905, Rietz 1912, Creaser 1931, 1932.
Orconectes rusticus subspecies: Brown 1955.
Orconectes rusticus placidus: Brown 1955.
Orconectes rusticus: Hobbs 1972.
Described from the Ohio River at Cincinnati, *Orconectes rusticus* is known in Illinois with certainty only from the Illinois River. Old records needing confirmation exist for other central and southern Illinois localities

Orconectes virilis (Hagen 1870)

Cambarus virilis Hagen 1870, Smith 1874, Forbes 1876, Faxon 1885, Underwood 1886, Harris 1903, Ortmann 1905, Rietz 1912, Faxon 1914, Jewell 1920, Ortmann 1931, Creaser 1931, 1932, Cralley 1932.

Orconectes virilis: Bovbjerg 1952, Brown 1955, Hobbs 1968, 1972.

Originally described from Lake Superior, *Orconectes virilis* is widely distributed and common in rocky and sandy habitats in Illinois although rare in the southern part of the state.

Fallicambarus fodiens (Cottle 1863)

Cambarus argillicola: Faxon 1890, 1914, Harris 1903, Ortmann 1905, Rietz 1912.

Cambarus fodiens: Creaser 1931, 1932, Hobbs 1948, Bovbjerg 1952, Brown 1955.

Fallicambarus fodiens: Hobbs 1972.

Described from Ontario (Huntsman 1915), *Fallicambarus fodiens* is a burrowing inhabitant of wooded areas in eastern and southern Illinois.

Cambarus diogenes Girard 1852

Cambarus obesus Hagen 1870, Smith 1874, Forbes 1876.

Cambarus diogenes: Faxon 1885, 1914, Underwood 1886, Harris 1903, Rietz 1912, Ortmann 1931, Creaser 1931, 1932, Cralley 1932, Bovbjerg 1952.

Cambarus diogenes subspecies: Brown 1955.

Cambarus diogenes diogenes: Marlow 1960, Hobbs 1969, 1972.

A common and widely distributed burrower in Illinois, *Cambarus diogenes* was originally described from Washington, D.C.

Cambarus laevis Faxon 1914

Cambarus bartoni subspecies: Rietz 1912.

Cambarus bartonii laevis: Brown 1955.

Cambarus laevis: Hobbs 1968, 1969, 1972.

An inhabitant of springs and spring-fed streams in extreme southeastern Illinois, *Cambarus laevis* was originally described from specimens collected in Monroe County, Indiana.

Cambarus ortmanni Williamson 1907

Cambarus ortmanni: Hobbs 1968.

Originally described from Wells County, Indiana, *Cambarus ortmanni* was erroneously reported by Hobbs (1968) to occur in Illinois.

Cambarus robustus Girard 1852

Cambarus bartonii robusta: Faxon 1885, Underwood 1886.

Cambarus bartoni robustus: Harris 1903, Rietz 1912.

Cambarus robustus: Creaser 1932, Brown 1955, Hobbs 1972.

Described from near Toronto, Canada, *Cambarus robustus* has been reported from Illinois by several authors; however, if present the species is exceedingly rare, and the distribution in the state is unknown.

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POLYCOTYLEDONY AND MORPHOGENESIS OF THE INFLORESCENCE AND FLOWER IN COLLINSIA HETEROPHYLLA

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ABSTRACT. – The polycotyledony and the double (split) leaves in Collinsia heterophylla Buist are considered as precocial manifestations of the action of the Pc-locus, which is assumed to be involved in the formation of the trimerous whorls of the inflorescence. The pentamerous cycles of the inflorescence and flowers appear to be the result of a combination of a bimerous and a trimerous node.

Genetic analysis of Collinsia heterophylla Buist (Scrophulariaceae) conducted by Goršič (1973) revealed that the polycotyledony (schizocotyly) is a simple recessive trait. The polycotyledony is known to occur in more than 30 families of Dicotyledoneae (Compton 1913, Earle 1938, Johnson 1936, Puri 1941, Swamy 1949). The wide-spread occurrence of this trait and the existence of pure-breeding polycotyledonous lines, in the normally dicotyledonous species, suggests the possibility that the gene(s) for polycotyledony (Pc-locus) may be a part of the normal genetic make up (genome) of plants of many, possibly all, families of Dicotyledoneae. If so, then, it is reasonable to assume that the Pc-locus may be involved in a control of some basic pattern of morphogenesis in plants.

Over 2000 plants were grown in the green-house (method for raising plants has been reported by Goršič, 1957). The modifications of leaf development and the number and arrangement of leaves of the polycotyledonous plants were compared with the morphological characteristics and the number and arrangement of bracts in the whorls of the inflorescence. In addition, the sequence of the maturation of flowers in the individual whorls was recorded.

In this article an attempt is made to explore the role the Pc-locus may play in the formation of the inflorescence and in the formation of the pentamerous flowers in C. heterophylla.

OBSERVATIONS AND INTERPRETATIONS

Polycotyledonous seedlings of C. heterophylla (Figs. 1-3) may have one normal and one split (double) cotyledon (1.2), both cotyledons split (2.2), three distinct cotyledons (1.1.1), one normal and one twice (1.3) or three times (1.4) split cotyledon, etc. Plants of this species have a decussate leaf arrangement. One leaf of the pair is usually larger. The leaves of the polycotyledonous plants tend to split - become double - (Figs. 4-6). Tricotyledonous plants commonly produce three leaves per node. Polycotyledonous plants in which the nodes with normal leaves alternated with the nodes having

one leaf split (Fig. 4), and plants in which the nodes with normal leaves alternated with the nodes having both leaves split (Fig. 6) have been observed. Plants having two nodes combined into a tetramerous whorl of four leaves as the result of the inhibition of elongation of the internode have also occurred (Fig. 7). These features of leaf and node configuration appear abnormal but, as will become apparent later, they reflect the normal stages of the development of the inflorescence and flowers.

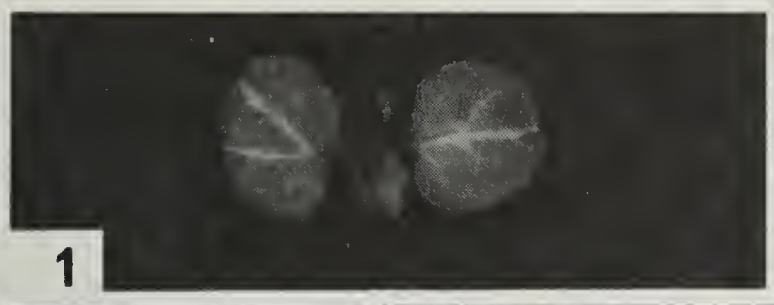
The reproductive growth-pattern in C. heterophylla was usually initiated at the fifth node or higher nodes in plants of certain genotypes and in plants grown in light of low intensity. Leaves at that level of plant development became sessile, the blade widened at the base, one leaf of the pair split, and the result was a trimerous whorl of large bracts (Fig. 8). The first whorl of the inflorescence had either three distinct bracts and 1-3 flowers; or one entire bract with or without an axillary flower, and a split (double) bract with one, two or no axillary flowers (occasionally the entire and double bract became connate, Fig. 8). Rarely the lowermost node of the inflorescence had two leaf-like bracts and one or two flowers. Plants with a four- or five-flowered whorl at the base of the inflorescence occasionally appeared.

These variations in the number of bracts and flowers at the first node of the inflorescence indicate that the transition from the vegetative growth-pattern to the reproductive growth-pattern occurs in some plants more abruptly than in other plants.

The second and higher nodes of the inflorescence had typically 3-5 flowers; the whorls with five flowers were prevalent. Two types of pentamerous whorls were observed: (a) in some, three flowers subtended by larger bracts matured ahead of the remaining two flowers subtended by smaller bracts (Fig. 10); (b) in other whorls two flowers were ahead in the development and three lagged behind (Fig. 11). In tetramerous whorls carrying five flowers one bract was always split (Figs. 9, 12). The typical tetramerous whorls were also of two types: (a) in some, two adjacent flowers matured slightly ahead of the remaining two; (b) in others, opposite flowers opened in succession with a 2-3 days interval (Fig. 13).

Thus, the formation of the inflorescence of C. heterophylla may be outlined as follows. The splitting of one of the two bract primordia at a node results in a trimerous whorl. Normally, the splitting of a bract occurs at every second node, but it may occur at adjacent nodes, or it may be skipped. The inhibition of elongation of alternate internodes results in a combination of nodes of the peduncle in a two by two pattern. The combination of a bimerous plus bimerous node results in a tetramerous whorl (another type of the

PLATE 1. Collinsia heterophylla. FIGURE 1. Semitricotyledonous (1.2). FIGURE 2. Semitetracotyledonous (2.2). FIGURE 3. Tricotyledonous (1.1.1). FIGURE 4. A double (split) and a normal leaf of the sixth (left) and seventh (right) node. FIGURE 5. Split leaf of the second node. FIGURE 6. Two split leaves of the fifth node (left) and two normal leaves of the sixth node (right). FIGURE 7. A whorl of four leaves. FIGURE 8. A trimerous (1.2) whorl of the inflorescence. FIGURE 9. A tetramerous whorl of the inflorescence with a double bract.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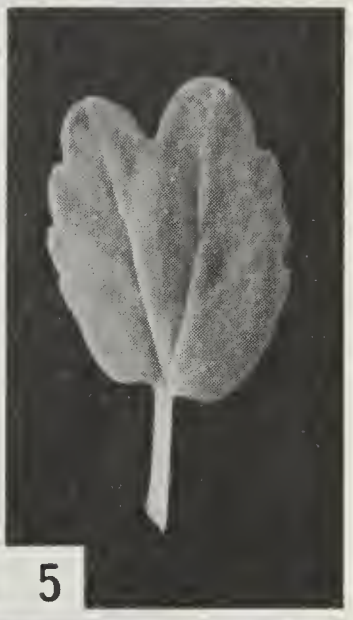
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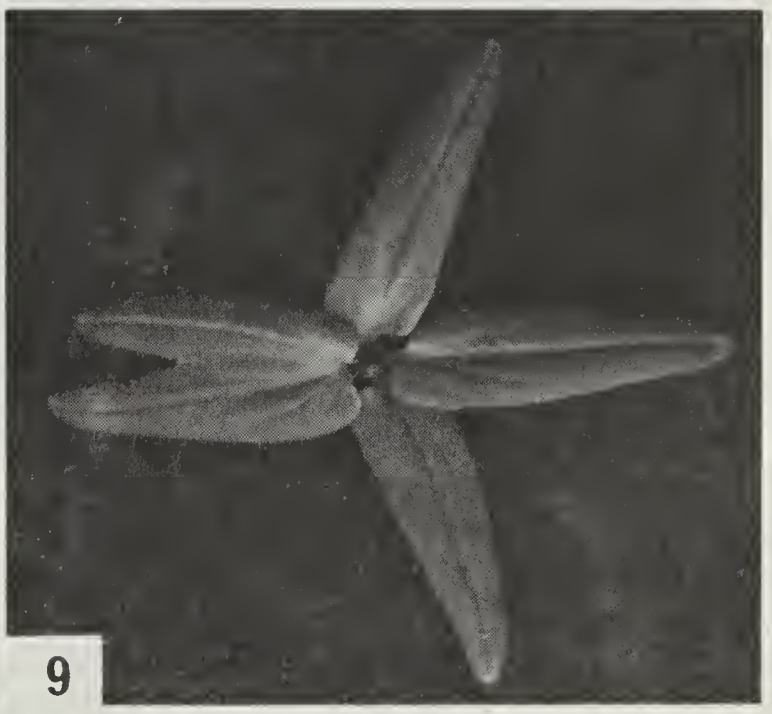
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PLATE 2. Collinsia heterophylla. FIGURE 10. The 3-2 pattern of the maturation of flowers in a pentamerous whorl. FIGURE 11. The 2-3 pattern of maturation of flowers in a pentamerous whorl. FIGURE 12. A tetramerous whorl with a double bract having two fused flowers in its axil. FIGURE 13. The opposite (2-2) pattern of the maturation of flowers in a tetramerous whorl.

tetramerous whorl is produced when both primordia at a node split). The combination of a bimerous plus trimerous node results in a whorl of five bracts. The combination of a bimerous plus semitrimerous (1.2) node results in a whorl of five bracts two of which are connate (Figs. 9, 12). The combination of a trimerous plus trimerous node (Figs. 14-15) or a semitrimerous plus semitrimerous node (Fig. 16) results in a whorl of six bracts. Another hexamerous whorl is produced by the combination of a tetramerous plus bimerous node. The combination of a trimerous plus tetramerous node results in a whorl of seven bracts (Figs. 17-18). Splitting of both primordia at two adjacent nodes and the subsequent joining of the two resulting tetramerous nodes is one of the possible methods that yields a whorl of eight bracts (Fig. 19).

The 7-12-bracteate whorls were regularly produced by the mutant, terminal rosette (beaked) bk (Fig. 20). In this mutant the high incidence of splitting of bract primordia and/or the inhibition of elongation of two or more successive internodes resulted in whorls with exceptionally high numbers of bracts.

The flowers in the individual whorls of the inflorescence matured as follows (Table 1). At the nodes with two flowers, the flower in the axil of the larger bract opened slightly ahead of the other flower. In the trimerous whorls two flowers opened slightly ahead of the third, or one opened slightly ahead of the remaining two. In all compound whorls (made up of two or more nodes) the flowers of the lower (older) node matured 2-3 days ahead of the flowers of the upper (younger) node. Thus, in the tetramerous whorls opposite flowers matured in succession with a 2-3 days interval (2-2 pattern, Fig. 13). In the pentamerous whorls three flowers opened 2-3 days ahead of the remaining two (3-2 pattern, Fig. 10), or two flowers opened 2-3 days ahead of the remaining three (2-3 pattern, Fig. 11). Two of the three flowers that matured in unison were adjacently located. It is assumed that in the first case (3-2 pattern) the split of one bract primordium occurred at the lower node of the whorl, and in the latter case (2-3 pattern) one bract primordium of the upper node had split. Whorls with the 3-2 and 2-3 pattern of the maturation of flowers occurred interchangeably in the same inflorescence. The tendency to adhere to the 3-2 or 2-3 pattern was noticed in some plants. In the hexamerous whorls the alternate (3-3) pattern of the maturation of flowers was prevalent (Fig. 15); less common were 4-2 (four older, two younger opposite flowers) and 2-4 patterns. Flowers of the heptamerous whorls matured in a 3-4 or 4-3 (four older, three younger flowers) pattern in such a way that two of the four flowers that matured in unison were adjacently located, and the remaining five flowers of the whorl alternated as to their age (Fig. 18). In the whorls with eight or higher number of bracts, the flowers were usually of three categories. A nine-flowered whorl exhibited clearly a 4-2-3 pattern (four oldest flowers alternated with two younger opposite flowers, and three youngest flowers, two of them adjacently located).

The pattern of the development of the inflorescence seems to be adhered to in the morphogenesis of the flower. The typical pentamerous whorl of the

PLATE 2 (continued). FIGURE 14. A hexamerous whorl (1.1.1 + 1.1.1). FIGURE 15. The alternate (3-3) pattern of the maturation of flowers in a hexamerous whorl. FIGURE 16. A hexamerous whorl (1.2 + 1.2); two bracts, one of each node, have fused. FIGURE 17. A heptamerous whorl.

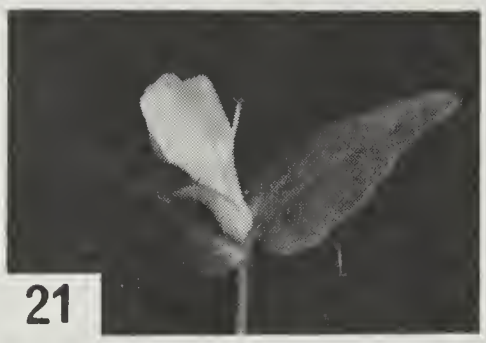

PLATE 3. Collinsia heterophylla. FIGURE 18. The 4-3 pattern of the maturation of flowers in a heptamerous whorl. FIGURE 19. An octamerous whorl. FIGURE 20. The terminal rosette phenotype with seven flowers at the first node of the inflorescence. FIGURE 21. The terminal flower. FIGURES 22-23. Incompletely developed calyces of terminal flowers. FIGURE 24. Adjacently positioned stamens of flowers with a tetramerous corolla and a pentamerous androecium. FIGURE 25. Sporadic polypetaly - the lower lip of the corolla with a double side lobe. FIGURE 26. A tetramerous flower.

inflorescence is reflected in the pentamerous cycles of the floral parts.

The flower of C. heterophylla has a five-lobed calyx, and a zygomorphic corolla composed of five united petals. The corolla has a two-lobed upper lip and a three-lobed lower lip (having two side lobes and a folded middle lobe

TABLE 1.– Patterns of flower maturation in the individual whorls of the inflorescence in Collinsia heterophylla

No. of bracts (flowers) per whorl	No. of bracts at the nodes making up the whorl 1-st 2-nd 3-rd	Pattern of maturation of flowers* 1-0	1-1	1-2	2-2^{o}	2-2^{a}	2-3	3-2
2	1.1 --- ---	+	+	-	-	-	-	-
3	1.2 --- ---	-	-	+	-	-	-	-
4	1.1 1.1 ---	-	-	-	+	-	-	-
	2.2 --- ---	-	-	-	-	+	-	-
5	1.1 1.2 ---	-	-	-	-	-	+	-
	1.2 1.1 ---	-	-	-	-	-	-	+

No. of bracts (flowers) per whorl	No. of bracts at the nodes making up the whorl 1-st 2-nd 3-rd	3-3^{al}	2-4	4-2	4-3	3-4	4-4	4-2-3
6	1.2 1.2 ---	+	-	-	-	-	-	-
	1.1 2.2 ---	-	+	-	-	-	-	-
	2.2 1.1 ---	-	-	+	-	-	-	-
7	2.2 1.2 ---	-	-	-	+	-	-	-
	1.2 2.2 ---	-	-	-	-	+	-	-
8	2.2 2.2 ---	-	-	-	-	-	+	-
9	2.2 1.1 1.2	-	-	-	-	-	-	+

* ◯ ○ - Flowers of the 1-st node (older)
○ - Flowers of the 2-nd node (younger)
• - Flowers of the 3-rd node (youngest)
⊙ - Peduncle
^{a} adjacent ^{al} alternate ^{o} opposite

called keel). Attached to the basal part of the corolla tube, in alternate arrangement with the petals, are five stamens (the stamen located between the lobes of the upper lip is reduced to a staminodium; the filaments of the upper two stamens are hairy and spurred). The pistil is composed of two united carpels. The ovary is superior, two-locular, and contains about 18 ovules.

Flowers of the polycotyledonous plants and flowers of the wild-type plants were morphologically identical (pentamerous).

PLATE 3 (continued). FIGURE 27. Polypetaly - three-lobed upper lip of the corolla. FIGURE 28. Polypetaly - the lower lip of the corolla with two side lobes and four keels.

The tetramerous flowers with four sepals, four petals, and four stamens have been observed (Fig. 26). Some plants developed terminal flowers at the first node of their uppermost branches (Fig. 21). The calyces of these flowers were incompletely developed; three sepals were associated with two vegetative leaves (Fig. 22), or four sepals were associated with one vegetative leaf (Fig. 23). In the terminal flowers having a tetramerous corolla and a pentamerous androecium two stamens were adjacently positioned (Fig. 24). – This observation supports the hypothesis of the autonomy of cycles in floral morphogenesis. – The pistils of the terminal flowers were normal. Similar heteromerous flowers (partly tetramerous partly pentamerous) were observed among the flowers of normal inflorescences.

This inconsistency in the number of floral parts indicates that here too, as in the morphogenesis of the inflorescence, the splitting of a primordium of a floral organ may not occur, and the result is a tetramerous cycle. On the other hand, the sporadic occurrence of polysepalous, polypetalous (Fig. 25), polystaminous and polycarpellate flowers in the inflorescences with normal flowers indicates that a primordium of any floral organ may split repeatedly, or that two or more primordia of an organ may split.

Two types of polypetalous flowers were observed in this study (Figs. 27--28). In the polypetalous-1 type the increase in the number of petals of the upper and/or the lower lip of the corolla was associated with a comparable increase in the number of the stamens. The supernumerary lobes of the corolla of these flowers were of two types: (a) major lobes with a true midvein, and (b) minor lobes with a midvein derived from the lateral vein of the adjacent petal (petals and sepals of normal flowers have a midvein and two lateral veins).

Corolla of the polypetalous-2 flowers had 1-3 additional major lobes in the lower lip, and, rarely, an extra stamen associated with the lower lip. The upper lip of the corolla of the polypetalous-2 flowers was not affected. Pistils of the polypetalous-2 and polypetalous-1 flowers were normal.

DISCUSSION

The arrangement of bracts of the unequal size in the whorls and the pattern of the maturation of flowers in the individual whorls of the inflorescence, as well as the configuration of the incompletely developed calyces of the terminal flowers, corroborate the hypothesis that the pentamerous whorls are the result of the combination of a bimerous and a trimerous node.

The phrase "splitting of primordia", used throughout this article, stands for the "initiation of new growth centers". The increase of the number of organs per node is the characteristic of the reproductive growth-pattern. A double bract (Figs. 8, 9, 12, 16) may develop when two growth centers are initiated in the area where one bract primordium normally occurs. At a later stage two such closely positioned primordia may fuse, but retain two growth centers, and develop into a double bract with two flowers in the axil (Fig. 12). A double bract carrying one flower in the axil (Fig. 16) would develop when two growth centers are initiated in that part of the apical meristem which has already been induced to develop into a bract primordium; such double bract is functionally one bract and can truly be referred to as being split.

Morphogenetically of great interest is the formation of the minor lobes in the polypetalous-1 flowers. The minor lobes are produced as the side lobes of the petals. At the site where the adnate filament of the stamen becomes detached from the tube of the corolla, the lateral vein of the adjacent petal enlarges and assumes the role of the midvein of the minor lobe. When, during the early stage of the flower development, the filament of the stamen does not attach itself properly along the line of connation of two petals but slightly to one side, then the lateral vein of the petal and the vascular bundle of the stamen are brought into a close proximity or become superimposed. Under these conditions, it appears, the regulatory influence of the growth center of the stamen is transferred to the adjacent petal's lateral vein enabling it to function as a midvein, and the result is the formation of a minor lobe. In contrast, the major lobes (having a true midvein) of the polypetalous-1 and polypetalous-2 flowers develop upon the initiation of new growth centers at the level of inception of the petal primordia.

The tendency to increase the number of primordia - that is, to initiate new growth centers - of the organs with the determinate growth (cotyledons, leaves, bracts, floral organs) of C. heterophylla presents itself as a continuum, which, in the wild-type plants, appears to be repressed during the vegetative stage, but in the polycotyledonous plants the repression mechanism seems to be broken down.

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THE INFLUENCE OF ABSCISIC ACID ON THE RESPIRATORY ACTIVITY OF POTATO TUBER TISSUE

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Abstract

Potato tuber tissue was physiologically aged in the presence of abscisic acid (ABA). In addition, the influence of cyanide and malonic acid on the respiratory rates was measured. Changes in respiratory rates and in the sensitivities to these inhibitors were determined. Abscisic acid exhibited an inhibitory effect on the respiratory activity of the potato tuber tissue. ABA did not, however, alter the typical developmental pattern with regard to changes in sensitivities to cyanide and malonic acid.

The term "physiological aging" is used by plant physiologists to describe the events that occur when thin slices of storage tissue are incubated after being cut from a root or tuber. The slices are maintained in distilled water, tap water, or a dilute calcium salt solution and are usually aerated. It has long been known that these freshly cut tissues show an immediate increase in respiration over that of the intac organ. This rise in respiration has been referred to as "wound respiration" (Laties, 1957). Furthermore, these tissue slices exhibit an additional respiratory rise during one to several days of incubation. The respiratory metabolism of plant storage organs can be separated into two components, basal and induced (Laties, 1957). The latter respiratory rate may differ qualitatively and/or quantitatively from the basal respiration (Laties, 1959; 1962; Romberger and Norton, 1961). Several line of evidence indicate that some biochemical pathways used by fresh tissue are distinct from those of aged tissue. The use of certain metabolic inhibitors allows these distinctions to be made. The effects of cyanide on terminal oxidation and malonic acid on tricarboxylic acid (TCA) cycle metabolism have been described by others. Their effects upon fresh and aged tissues are specific. Cyanide greatly suppresses oxygen uptake in fresh tissue but has little influence on aged tissue (Hackett et al., 1960). Cyanide is a specific inhibitor of cytochrome oxidase, the terminal enzyme of the electron transport chain. Aged tissue, with its high rate of oxygen consumption coupled with phosphorylating ability, may develop a method to circumvent the cyanide inhibition present in fresh tissue (Laties and Hoelle, 1965). Changes also occur in TCA cycle

metabolism during aging since malonic acid, an inhibitor of succinic dehydrogenase, lowers the oxygen consumption of aged tissue but not of fresh tissue (Webb, 1966).

Abscisic acid (ABA) has been identified as a plant hormone (Ohkuma et al., 1963; Cornforth et al., 1965) and as a component of the inhibitor B-complex from many different species (Cornforth et al., 1966; Milborrow, 1967). ABA has been claimed to be the most important growth-inhibiting component of the B-complex (Milborrow, 1967). In many situations the effects of ABA were quite transient, and repeated applications were necessary to elicit a response. Plant tissues are well adapted to ABA in that the normal metabolic processes can respond readily to the substance either with some observable change in activity or, in some circumstances, by a rapid inactivation of the applied ABA (Addicott and Lyon, 1969). The role of ABA, like that of the other plant hormones, is complex and it conceivably exerts a primary regulatory effect at more than one site (Milborrow, 1969). Knowledge of the influence of ABA on the synthesis and activity of enzymes in the plant is still relatively meager.

MATERIAL AND METHODS

Potato tubers of Solanum tuberosum L., var Burbank Russet were purchased locally in one hundred pound lots and stored in the dark at 5 ± 2 C. Twelve hours prior to the experiment, the tubers were removed from cold storage and allowed to come to room temperature. Cylinders of tissue having a diameter of 8.0 mm were removed from the tubers and cut into 1.0 mm slices with a hand microtome. The slices were placed immediately in sterile distilled water kept at 0 - 3 C. The slices were rinsed with additional cold, sterile distilled water to remove free starch and then randomly separated into required lots. All aging solutions contained 1 x 10^{-4} M calcium sulfate and were buffered with 2.5 x 10^{-2} M N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid (HEPES, Sigma Chemical Co.), adjusted to pH 6.0. Abscisic acid (ABA, F. Hoffman-LaRoche and Co., Basle, Switzerland) was added as noted. Aging solutions were stored in the dark at 5 C until needed. Solutions were always made up fresh for each experiment.

The vessels used for aging potato tuber slices were a series of six sterile 150 ml glass Buchner funnels with a diameter of 6.5 cm. Each funnel was fitted with a coarse sintered glass bottom disk with a pore size of 40 - 60 microns. A compressed air line was attached to the stem of each funnel. To promote aseptic conditions air was first forced through a bacteriological filter and bubbled through sterilized water before it was allowed to enter the aging containers. The tissue was aged for a total of 48 hours at room temperature (25 ± 2 C) and under constant illumination by a cool white fluorescent tube. The tissue slices were agitated continuously by the sterile air bubbling through the aging solutions. The solutions were changed at 1, 2, 6, 12, 24, and 36 hour aging periods in order to maintain a constant concentration and pH, and to minimize microbial growth.

Aging was considered to begin when the tissue was removed from the chilled distilled water and added to the appropriate buffered solution at room temperature. Periodically sufficient slices were removed for respiratory measurements. Any particular tissue sample was measured

only once. Oxygen consumption was determined polarographically with a Clark oxygen electrode (Yellow Spring Instrument Co.). The measuring vials contained 8.0 ml of 5 x 10^{-2} M HEPES buffer at either pH 5.6 or pH 7.2. Temperature was maintained at 30 C (± 0.05 C) by means of a Haake constant temperature circulator. Data were recorded on a Varian (Model G-14 A) recorder set at 0.5 inches per minute. Rates for fresh and aged tissue were obtained using lots of eight and five slices, respectively.

Each tissue lot removed from the aging apparatus was first rinsed i distilled water, blotted dry, rapidly weighed to the nearest one tenth o a milligram and then equilibrated in vials with air-saturated buffer for 5 minutes prior to measurement. Where the influence of malonic acid or cyanide was studied, rate curves for uninhibited tissue were first estab lished. The inhibitors were then added directly to the vials and the respiratory rates determined for an additional 10 minutes. The final concentration of malonic acid was 5 x 10^{-2} M at pH 5.6 and of cyanide wa 5 x 10^{-3} M at pH 7.2. The two different pH's were used in order to ob- tain maximum responses to the two different inhibitors (Hanebuth, 1969). Duplicate samples were measured at each aging period.

RESULTS

Oxygen Consumption

Typical results of physiologically aging tissue slices in the presence of various concentrations of ABA, ranging from 10^{-6} to 10^{-3} M are shown in Figures 1 and 2. The data presented represent the mean fro five experiments for the various ABA concentrations. The data presented in Figure 1 are the respiratory rates of fresh and ABA-aged tissues

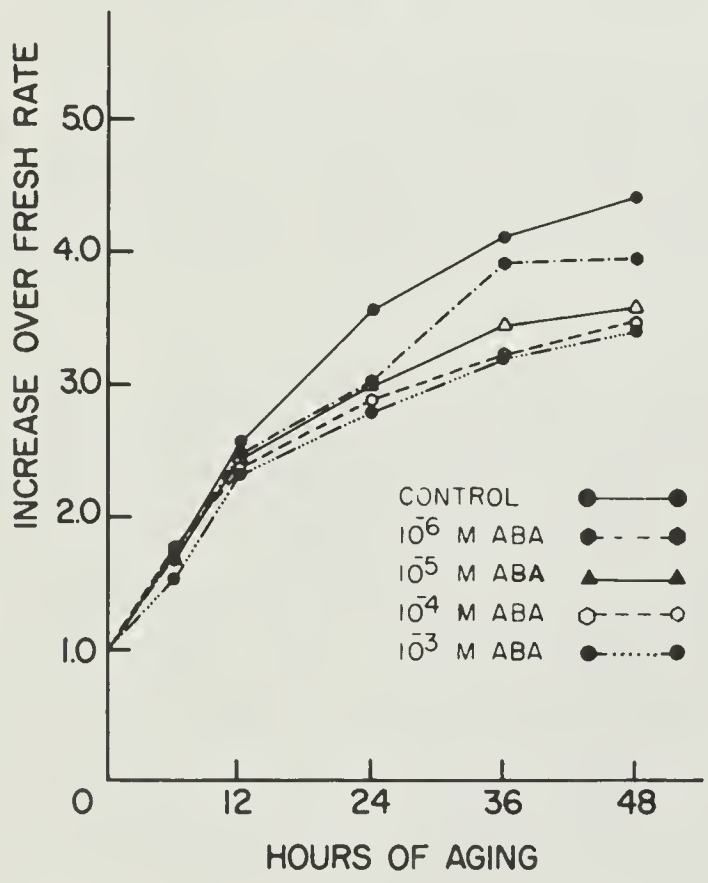

FIGURE 1. - Respiratory values of tissue slices measured at pH 7.2 after incubation in abscisic acid. The rate of fresh tissue was 1.66 ± 0.21 µmoles O_2 consumed/hr·g fresh weight.

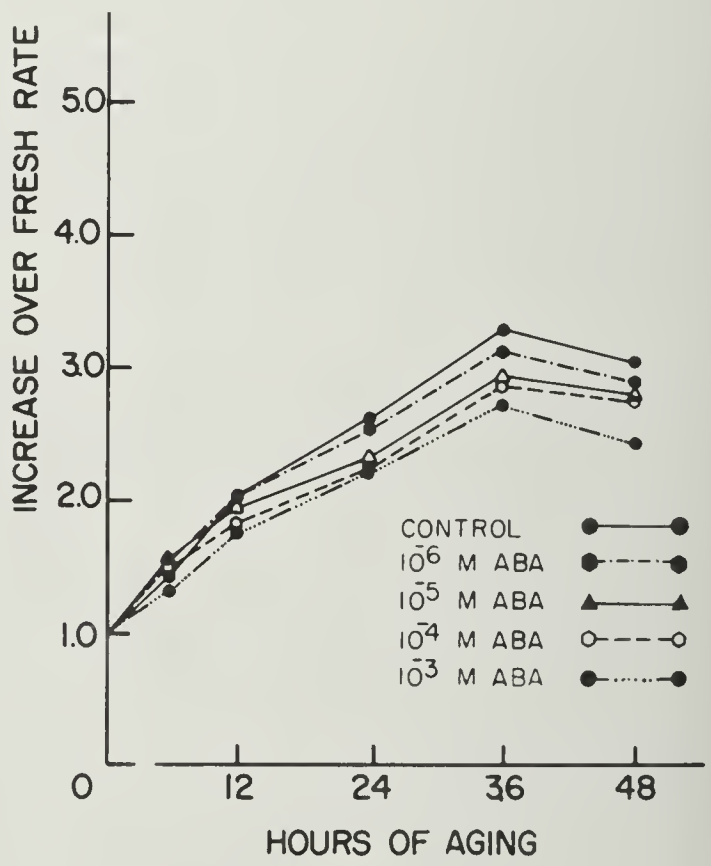

FIGURE 2. - Respiratory values of tissue slices measured at pH 5.6 after incubation in abscisic acid. The rate of fresh tissue was 1.83 ± 0.22 µmoles O_2 consumed/hr·g fresh weight.

measured at pH 7.2. In general, these values run 10 to 25 per cent higher than comparable rates determined at pH 5.6 (Fig. 2). As aging progressed, changes occurred in the oxygen consumption of the control tissues similar to that previously reported (Laties, 1957; Hanebuth, 1971). The respiratory rates showed the greatest increase during the first 12 hours of the aging period and the influence of ABA at all concentrations used was not apparent at this time. After 12 hours the slopes of the respiratory curves tend to level off with increasing aging time.

ABA had a measurable inhibitory effect on the respiratory activity of potato tuber tissues. This inhibition increased with increasing ABA concentrations. At 24 hours of aging the ABA inhibition reached 15 to 22 per cent when measured at pH 7.2 and 4 to 15 per cent when measured at pH 5.6 (Figure 3). At 48 hours of aging, the inhibition ranged from 10 to 23 per cent at pH 7.2 and 5 to 20 per cent at pH 5.6 (Figure 4). The data presented in Figures 3 and 4 are expressed as the percentage of the control value at 24 and 48 hour aging time, respectively. The level of the control treatment was used as 100 per cent activity.

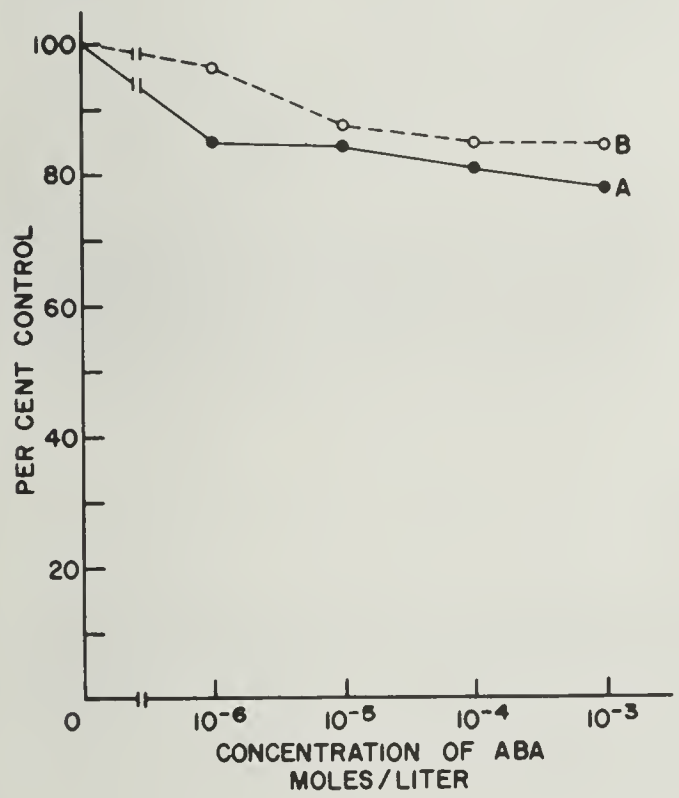

FIGURE 3. - Per cent control respiratory rates of tissue slices after incubation in abscisic acid for 24 hours. The level of control treatment is used as 100 per cent activity. The rates were measured at pH 7.2 (A) and pH 5.6 (B).

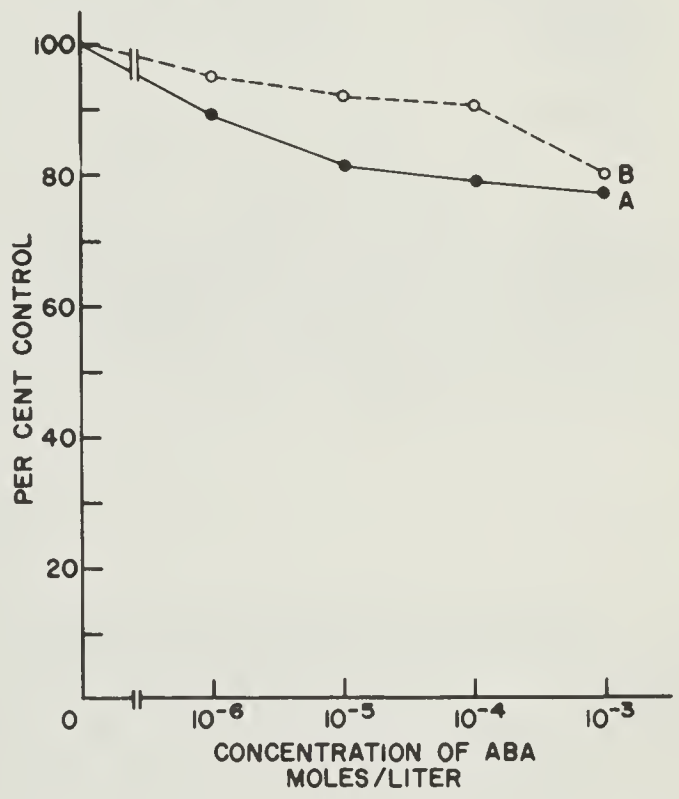

FIGURE 4. - Per cent control respiratory rates of tissue slices after incubation in abscisic acid for 48 hours. The level of control treatment is used as 100 per cent activity. The rates were measured at pH 7.2 (A) and pH 5.6 (B).

The Effect of Cyanide on ABA Aged Tissues

Addition of 5 mM potassium cyanide (pH 7.2) to fresh tissue reduced the respiratory rate of potato tuber tissue to 40 per cent of the cyanide-free control (Figure 5). By 36 hours of aging the control tissue became essentially cyanide insensitive. The data presented on the

respiratory rates of ABA-aged tissues were measured in the presence of 5 mM cyanide at pH 7.2. Compared with the cyanide-free measurement (Figure 1), during the first 24 hours of aging the comparable respiratory rates were lowered by 30 to 50 per cent.

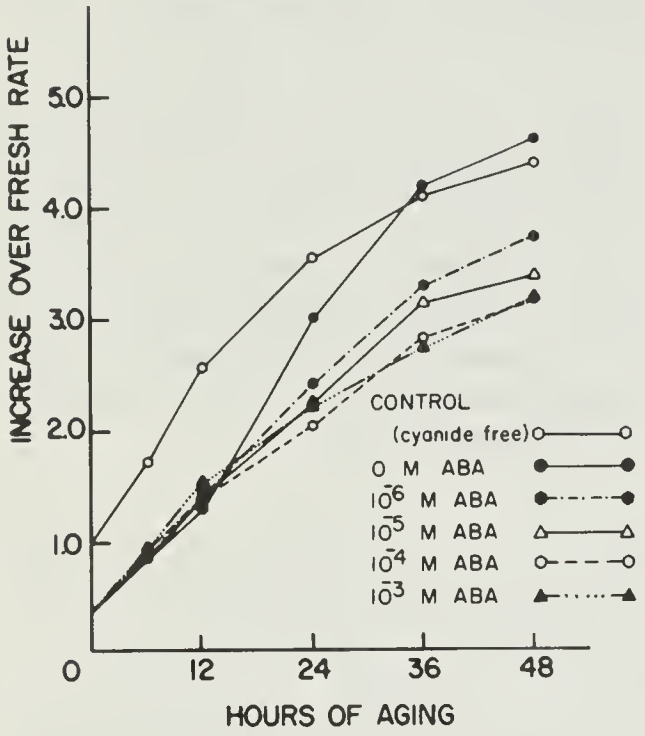

FIGURE 5. - The effect of potassium cyanide on the respiratory rate of tissue slices after incubation in abscisic acid. Control value is taken from Figure 1. Slices were aged in various concentrations of ABA and the rates of respiration were measured in 5 mM potassium cyanide at pH 7.2.

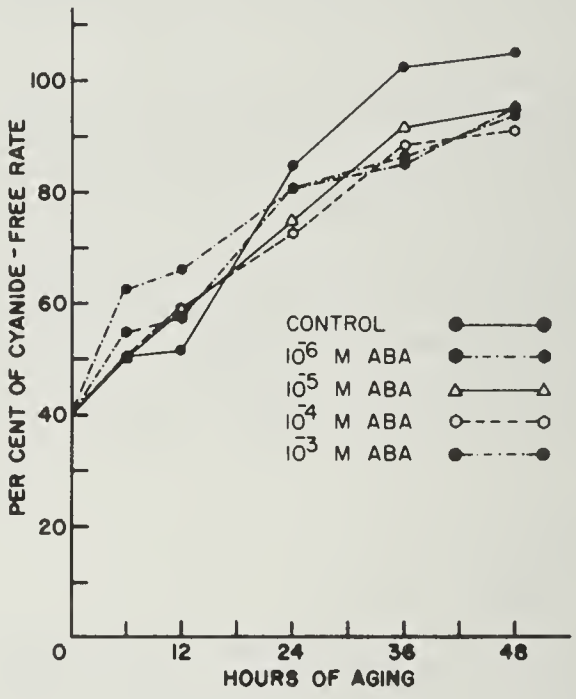

FIGURE 6. - Changes in cyanide sensitivity of abscisic acid aged tissue slices with time. The percentages are derived from the respiratory rates in the presence of potassium cyanide divided by the comparable rates in the absence of potassium cyanide.

As shown in Figure 6, ABA at all concentrations used had little effect on the loss of cyanide-sensitivity of the tissue with aging. These values are obtained by dividing the respiratory rates in the presence of cyanide by the rates in the absence of cyanide.

The Effect of Malonic Acid on ABA Aged Tissues

Addition of 50 mM malonic acid at pH 5.6 to fresh tissue, in contrast to cyanide, had essentially no effect on the respiratory rate (Figure 7). With aging the tissues showed an increase in malonite sensitivity. This occurred in both the control and the ABA treated slices. However, as shown in Figure 8, ABA at all concentrations used had little influence on the development of this sensitivity, just as it had an insignificant effect on the development of cyanide insensitivity (Figure 6) As before, these values were obtained by dividing the respiratory rates in the presence of malonic acid by the rates in the absence of malonic acid.

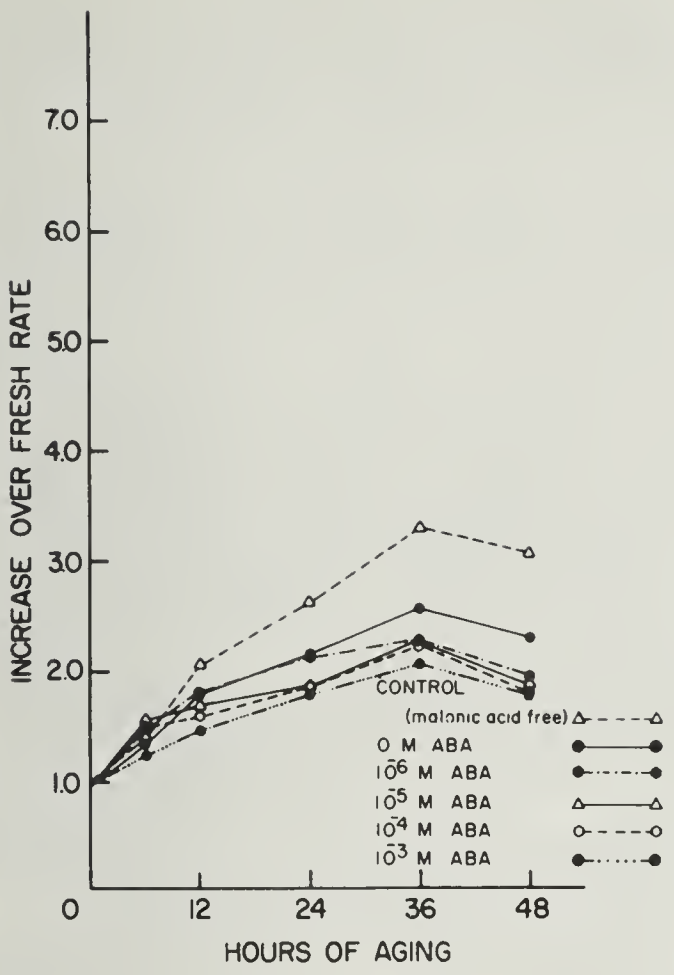

FIGURE 7. - The effect of malonic acid on the respiratory rate of tissue slices after incubation in abscisic acid. Control value is taken from Figure 2. Slices were aged in various concentrations of ABA and the rates of respiration were measured in 50 mM malonic acid at pH 5.6.

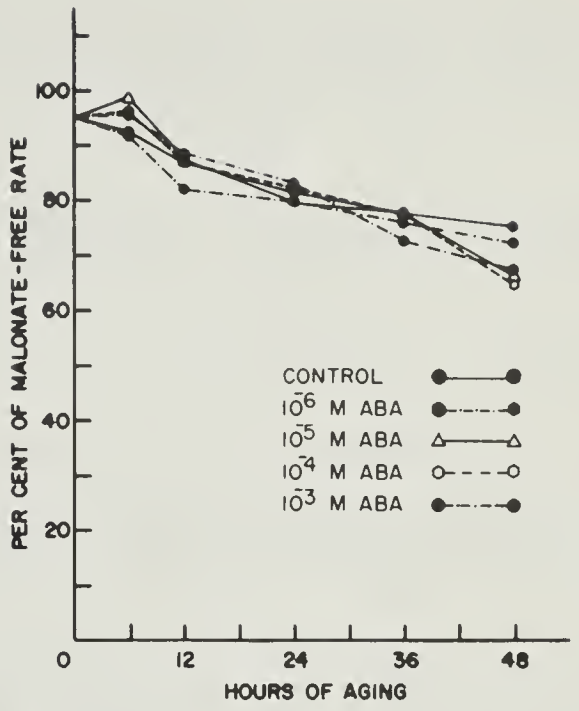

FIGURE 8. - Changes in malonate sensitivity of abscisic acid aged tissue slices with time. The percentages are derived from the respiratory rates in the presence of malonic acid divided by the comparable rates in the absence of malonic acid.

DISCUSSION

Although marked increases in respiratory activity have been observed in a wide variety of sliced storage organs, little is known about the mechanisms which control this enhancement. In recent years, it has become increasingly evident that growth regulating substances play a central role in the regulation of metabolic processes in plants. The enhancement of the respiratory rate of aged tissue can be influenced by many factors, e.g., thickness of the slices (Laties, 1962), the aging temperature (MacDonald and Dekock, 1958), and the washing and aeration conditions (Reed and Kolattukudy, 1966). Since respiration includes many enzymatic reactions, hydrogen ions may play a significant role in the reaction. As shown in this investigation, the respiratory rate was significantly different in two different hydrogen ion concentrations.

Considerable evidence already exists in the literature to show that ABA inhibits many physiological processes in plant tissue. One would expect that the ABA-treatment would reduce the respiratory activity of potato tuber tissue. From this investigation it is evident that ABA had a measurable inhibitory effect on the respiratory activity of the tissue, as great as 20 per cent after 48 hours. This inhibition increased with increasing ABA concentration. While the exact mode of the action of ABA is not known, there have been at least two possible mechanisms proposed

to explain this inhibitory phenomena. Based on the regulatory model of Jacob and Monod (1961), it has been suggested that ABA might exert its effect: (1) at the level of translation (Srivastava, 1968; Haber et al., 1969, or (2) at the level of transcription (van Overbeek et al., 1967; Wareing et al., 1968). Both have the same ultimate effect on protein (enzyme) synthesis. In this investigation the inhibitory effect of ABA may be due to a reduction in the synthesis of respiratory enzymes with a consequent reduction of the respiratory activity of the potato tuber tissue.

The cyanide and malonate inhibition studies may provide some evidence for the mechanism of the effects of ABA on the respiratory activity of potato tuber tissue. ABA had no significant effect on the tissue in terms of the development or loss of sensitivity to both inhibitors. Two possibilities for ABA's effect are: (1) ABA and the inhibitors (malonate and cyanide) act at the same level or the same point in the respiratory process, or (2) ABA acts at the enzyme synthesis level and inhibitors act at the enzyme activity level. From a comparison of the chemical structures and properties of these compounds, the possibility that they might react at the same point or level of the respiratory system seems fairly remote. That ABA might inhibit the synthesis of respiratory enzymes of potato tuber tissue is quite reasonable.

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NOTES ON SOME RARE ILLINOIS ORCHIDS

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ABSTRACT

Twelve species of Orchidaceae rarely collected in Illinois are treated. The literature is reviewed and incorrect reports revised. Several new collections, including range extensions, are reported.

For the past several years I have conducted an intensive study of Illinois Orchidaceae and for a period of fifteen years have studied these species in the field throughout the state. I have exhaustively studied and analyzed the literature and have examined the collections of thirty-four herbaria. A detailed account of the family, with emphasis on each species' distribution and ecology in the state, is in preparation, but it is perhaps desirable to make available at an earlier date, and in concise form, a few notes on some of the state's rarer species, especially those which have been poorly treated in the past or those for which substantial new discoveries have been made. Twelve taxa fall into such categories.

Cypripedium acaule Ait.

The Cass County report by Gates (1922) is doubtless erroneous This report is attributed to local residents, who often refer to C. reginae as "pink lady's slipper", and may thus have misled Gates.

Cypripedium acaule has been known from Cook County (Higley and Raddin, 1891; Pepoon, 1927; Jones and Fuller, 1955; and others); several additional specimens from other localities have been found. This species is now known to occur in four counties:

Cook County: Moist woods, rare, 6 plants, Elk Grove, Des Plaines, May 30, 1942. G. Pearsall 7329. (ISM).

Lake County: Tamarack forest in sphagnum bog, Volo Bog, northwest of Volo, 28 May, 1968. C. J. Sheviak 210. (in collector's herbarium);

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Moist woods, rare, Waukegan, 4 June, 1944. G. Pearsall 21a. (ISM). (This specimen is part of a mixed collection and may have been collected at Elk Grove.)

McHenry County: Hummock in tamarack forest, Wilson Bog, east of Pistakee Bay, 27 May 1972. A. W. Haney and C. J. Sheviak 510. (ILLS and latter collector's herbarium).

Ogle County: Sand rock woods, Ogle County, Illinois, May 22, 1960. W. S. Hooks 101. (Northern Illinois University) (There is some cause to suspect that this specimen was planted).

Habenaria dilatata (Pursh) Hook.

The report of this species from Lake County (Gates, 1912) is based on specimens of H. hyperborea and H. flava var. herbiola deposited at the Field Museum and the University of Illinois. The reports of H. X media (as H. dilatata var. media) from Lake County by Pepoon (1927) and Fuller (1933) are based on specimens of H. hyperborea and do not indicate the presence of H. dilatata in this area.

In Illinois, H. dilatata is known from three counties. It was reported from McHenry County by Swink (1969) and Mohlenbrock (1970), but the specimen upon which these reports were based could not be located during this study. The following collections are known:

Carroll County: Thompson Marsh, June 2, 1886, (without collector). (ILL).

Kankakee County: Near Kankakee, August 3, 1912. J. M. Greenman 3532. (MO).

Habenaria flava (L.) R.Br. ex Spreng. var. flava

In Illinois, this southern variety is limited to southern swamp forests in the Coastal Plain and lower Wabash valley. It is known from an early collection in Wabash County, and it has recently been discovered by John Schwegman in Massac and Johnson counties.

The report of this variety from St. Clair County by Mohlenbrock (1970) is apparently in error. The only St. Clair County specimen of H. flava which could be located during this study (Bluff Lake in ILLS, July 1878, H. Eggert, s. n.) is referable to var. herbiola. Because Mohlenbrock did not cite St. Clair County for this variety, and because this specimen is deposited at the Missouri Botanical Garden, which collection he examined, it appears that this specimen is the basis for this report. The resultant distributional pattern in Illinois is in agreement with the range of var. flava in Missouri, where it is limited to the southeast and does not extend up the Mississippi River valley (Steyermark, 1963).

The following Illinois collections are known:

Johnson County: Along Cache River below Wildcat Bluff, 3 miles southwest of Vienna, October 4, 1970. John Schwegman. (unmounted in collector's herbarium);

same locality, 2 August 1971. C. J. Sheviak 408. (in collector's herbarium, photograph deposited at ILLS).

Massac County: Black Bottom, bottomland forest with Onoclea, August 17, 1969. John Schwegman. (photograph and unmounted specimens in collector's herbarium).

Wabash County: Mt. Carmel, Ill., July 1890. M. Craig, s. n. (ILL).

Habenaria hookeri Torr. ex Gray

This species has long been known from Lake and Cook Counties, and the comparative abundance of collections suggests that it is not properly treated in this paper. However, the discovery of a collection which greatly alters the known range of H. hookeri in Illinois dictates that mention of this specimen be included here without citation of other collections. Although the previously known collections of this species indicate that it is limited to the northeastern portion of the state, especially the Lake Michigan border, the distribution of the species in Iowa and southern Wisconsin suggests a wider occurrence in Illinois. A search of the S. B. Mead herbarium at Knox College has revealed a collection from Hancock County (grows in woods west of Bob Browns, abundant. S. B. Mead s. n.). Kibbe (1952) reported that this locality was near Augusta, Hancock County. These specimens served as the basis for her report of H. orbiculata from that county.

A duplicate Mead specimen has been deposited at the University of Illinois.

Habenaria obtusata (Banks ex Pursh) Richards

This boreal species was reported by Correll (1950) as ranging south to " ... (?) Illinois (Kane County) ...." This report is based on a specimen collected by Boyce and now deposited at the Dudley Herbarium of Stanford University (Correll, personal communication). This specimen bears a label from the "Herbarium of State Normal School, Winona, Minnesota". Examination of the specimens on the sheet, however, revealed a partially decomposed Picea needle imbedded in the root mass of one of the specimens. This collection is thus not from Illinois, and the locality cited must refer to Boyce's place of residence, not the collection locality.

Habenaria orbiculata (Pursh) Torr.

Ames (1910) tentatively reported this species from Kane County, but the specimen at the Smithsonian Institution which served as the basis for his report bears Abies balsamea needles in its crown and thus was not collected in Illinois. The labeling of this specimen is identical with that of the H. obtusata specimen dealt with above. Kibbe's report (1952) of H. orbiculata from Hancock County rests on specimens of H. hookeri. Fernald (1933) attributed H. orbiculata to Winnebago County, but it has not been possible to verify this record. Such a colony would be a most unusual disjunct, and this report must remain questionable; it may involve a misidentification of H. hookeri.

At present, only two valid Illinois collections of this species are known. One, annotated H. orbiculata by D. S. Correll (Mohlenbrock, personal communication) was reported from Elgin, Kane County, by Mohlenbrock and Ozment (1967). This specimen could not be located for this study. An additional specimen, part of a mixed collection with H. hookeri, has been located:

Cook County: Evanston. (without collector or date) from the herbarium of Charles Raddin. (F).

Spiranthes lucida (H. H. Eaton) Ames

The reports of this species from Menard County (Patterson, 1876; Hill, 1899; Fernald, 1945) are based on E. Hall collections of S. ovalis deposited at the Field Museum. Considering the labeling of Mead's specimens, his report (1846) of S. aestivalis (Lamb.) L.C. Rich, is referred here. Raddin (1883) reported S. lucida (as S. latifolia, a synonym) from Cook County. The accuracy of this report is not known.

Spiranthes lucida has been known from 1844 and 1897 collections from Hancock and Will counties, respectively. It was recently discovered by D. A. Niemann and the author in Woodford County. A colony was located on a grazed shore bar of the Illinois River but was later destroyed by natural deposition of sand. The species, however, appeared to have recently invaded the site and probably still occurs in the vicinity.

The following collections are known:

Hancock County: Creek under hill north of Cain on old Carthage Road, May 29, 1844. S. B. Mead s. n. (Knox College).

Will County: Springy bog in wooded pasture southeast of Marley, June 22, 1897. Agnes Chase s. n. (Chicago Academy of Sciences).

Woodford County: Shore bar of Illinois River, SW¼ (100 feet south of NW¼) sec. 11, T. 27 N., R. 4 W., south of Spring Bay, 25 May 1968. D. A. Niemann and C. J. Sheviak 257. (in latter collector's herbarium; photograph deposited at ILLS).

Spiranthes romanzoffiana Cham.

This species displays a most interesting and perplexing distributional pattern in Illinois. Known from Cook, Peoria, and Coles counties, its stations in the latter counties are disjunct by 140 and 200 miles, respectively, from that in Cook, which lies on the southernmost edge of the general range of the species. This curious distribution is perhaps related to the occurrence of hanging fens along the Shelbyville Moraine, but why other fens are avoided is unknown.

The following collections are known:

Coles County: Near Lincoln Log Cabin, October 1947. E. L. Stover s. n. (Eastern Illinois University).

Cook County: Glencoe. August 5, 1873. Paul Blatchford 2525. (ISM).

Peoria County: Peoria. (without collector or date). (US).

Spiranthes vernalis Engelm. & Gray

Reports of this species by Illinois workers frequently are based on misidentifications of other species. The report of S. vernalis from Clark County (Hellinga and Ebinger, 1970) is based on S. cernua. The reports of S. vernalis from Menard County (Jones and Fuller, 1955; Jones, 1963; Mohlenbrock, 1970) are based on E. Hall specimens of S. ovalis deposited at the Field Museum.

Many specimens of S. cernua from southern Illinois have been found labeled S. vernalis. This situation results from the often high angle of the parastichy in material of S. cernua from our area, thus presenting a single-ranked aspect to the inflorescence and permitting these plants to be keyed to S. vernalis. Attention should be given to the nature of the indument, which in S. vernalis is composed exclusively of sharp-pointed hairs, but in S. cernua exhibits at least some capitate trichomes.

The following Illinois S. vernalis specimens are known:

Effingham County: Grassy right-of-way of I.C.R.R. 5 miles south of Watson, July 8, 1951. G. S. Winterringer 7218. (ISM).

Massac County: Old field (with Andropogon sp.), Mermet Refuge, June 22, 1965. John Schwegman 48. (SIU).

Pope County: Woods around Lake Glendale, near Dixon Springs, August 16, 1960. A. C. Koelling 203. (ILL);

SW¼, NE¼, NE¼, sec. 2, R. 5 E., T. 13 S., Brownfield Quad., August 8, 1964. John Schwegman s. n. (SIU);

old field, southwest of Bay City, July 23, 1970. R. A. Evers 103101. (ILLS);

in old field of Andropogon scoparius, NW¼, SW¼, sec. 14, T. 15 S., R. 6 E., southwest of Bay City, 2 August 1971. C. J. Sheviak 407. (in collector's herbarium).

St. Clair County: Cahokia, August 13, 1891. E. Douglass s. n. (MO).

Wabash County: Vicinity of Mt. Carmel, September 1877. Harry Patterson s. n. (F);

along railroad southwest of Mt. Carmel, July 9, 1968. R. A. Evers 96388. (ILLS).

Malaxis monophyllos (L.) Sw. var. brachypoda (Gray) Morris & Eames.

The report of this species (as Microstylis monophyllos, a synonym) from Menard County (Patterson, 1876) is evidently in error. Patterson's report reads, "Swamps. Menard County, Brendel; Elgin, Kane County, Vasey". In the University of Illinois herbarium is Brendel's copy of the Patterson catalogue. In this copy, Brendel has crossed out the Menard County report, and this record is thus here considered to be erroneous.

The reports of M. unifolia from Kane County (see below) are based on this species.

Mohlenbrock and Ozment (1967) recently reported an Illinois specimen of this species. Since then, an additional specimen has been located. It has served as the basis for incorrect reports of M. unifolia from Kane County. The following specimens are known:

Kane County: Elgin Swamp, Ill. Vasey s. n. (Illinois State University).

Illinois, without proper locality: Bogs, Ill. (without date or collector). (MO).

Malaxis unifolia Michx.

This species apparently has been collected in only three west-central counties, although Jones (1945), Jones and Fuller (1955), Jones (1963), Swink (1969), and Mohlenbrock (1970) reported it from Kane County. These reports are evidently based on the Elgin specimen of M. monophyllos var. brachypoda referred to M. unifolia by Jones (1945).

The following specimens are known:

Hancock County: Dry woods, Augusta, July 12, 1852. S. B. Mead s. n. (AMES);

Illinois, 3.5 WsW 10 NW 1 or 2, nearly out of flower, July 12, 1852. S. B. Mead s. n. (Knox College);

One additional Knox College Mead collection is known and is probably from Hancock County.

Henderson County: In woods, near Oquawka, June 13, 1872. H. N. Patterson s. n. (F).

Menard County: Woods, Athens, 1861. E. Hall s. n. (F, ILL, ISM, NY);

Athens, August 1866. E. Hall s. n. (F);

Menard County, E. Hall s. n. (Illinois State University);

Menard County, (without collector or date). from the herbarium of Frederick Brendel. (ILL).

Corallorhiza trifida Chat.

This species was reported from St. Clair County by Mohlenbrock and Ozment (1967) and Mohlenbrock (1970). These reports are erróneous, as the specimens upon which they are based (St. Clair County, Hillsides, May 10, 1897. J. Kellog s. n.), deposited at the Missouri Botanical Garden and bearing Mohlenbrock's annotation, are all C. wisteriana.

This species has also been reported from Hancock County (Kibbe, 1952), but the specimen upon which this report is based (W. June 1. N. L. pond N. W. end. S. B. Mead s. n.), at Knox College, is labeled Neottia aestivalis; this suggests a mixture of labels.

The only apparently valid report of this species from Illinois is that of Higley and Raddin (1891), who reported it (as C. innata, a synonym) from Cook County in an area adjacent to known colonies in Indiana. This report is thus here considered to be valid, even though the specimen, reported as deposited at the University of Chicago (whose collection is now deposited at the Field Museum), could not be located. It should be noted that no misidentifications which could have contributed to this report were found, and some other specimens of other species similarly reported by Higley and Raddin as deposited in this herbarium have not been located; a loss of specimens is thus apparent.

ACKNOWLEDGEMENTS

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THE IDENTIFICATION, ISOLATION AND CHARACTERIZATION OF SOME CARBOHYDRASES PRESENT IN DEBARYOMYCES HANSENII

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ABSTRACT

The soluble carbohydrases α-D-galactosidase, β-D-fructofuranosidase, and trehalase were isolated from Debaryomyces hansenii. About 120-fold and 50-fold purifications were obtained with β-D-fructofuranosidase and trehalase, respectively. Broad optimal pH's existed around pH 5 for both of these enzymes. The Michaelis constant for β-D-fructofuranosidase was 0.017 M (0.1 M acetate, pH 5.5, 37°C, with sucrose as the substrate).

INTRODUCTION

Debaryomyces hansenii is a sporogenous yeast capable of reproducing itself in aqueous solutions nearly saturated with sodium chloride at temperatures near the freezing point of water. Occasionally it finds its way from its marine habitat into a variety of food products via the production of solar salt.

Merdinger et al. have investigated the nutritional requirements, the lipid composition, and the response to various anesthetics of this organism (Merdinger and Shair, 1962; Merdinger, 1965; Merdinger and Devine, 1965; Merdinger and Frye, 1966; Merdinger, Guthmann and Mangine, 1969). The purpose of this investigation was to isolate and characterize some of the carbohydrases present in uninduced Debaryomyces hansenii.

MATERIALS AND METHODS

The yeast was grown under aeration in a fermenter at 30°C in an aqueous solution at pH 5.5. Each 100 ml contained the following: 2.0 gm glucose, 1.5 gm NaCl, 0.5 gm $(NH_4)_2SO_4$, 0.3 gm malt extract, 0.3 gm yeast extract, 0.1 gm asparagine, and a mixture of nutrient salts containing lesser amounts of K, Mg, Ca, Fe, Cu, An, I, and P. After harvesting by centrifugation and checking microscopically for purity, cells were suspended in 0.1 M acetate, pH 5.5, and ruptured at 5°C for 35 minutes with 125 μm diameter glass beads in a Sorvall Omni-mix. Microscopic examination revealed greater than 90% breakage of cells.

This homogenate was centrifuged at 600 x g for 20 minutes. The sediment was then subjected to 25,000 x g for 30 minutes, the supernatant liquids combined, and the sediment discarded. Differential centrifugation was used to sediment different cell organelle types. The final centrifugation (120,000 x g for 2 hours) yielded a supernatant liquid containing only the soluble proteins.

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Precipitation of some of these proteins was achieved by the slow addition of ammonium sulfate to a portion of the 120,000 x g supernatant liquid with stirring at 5°C. When the concentration reached 40% of saturation, the stirring was continued for one hour. The suspension was then centrifuged at 25,000 x g for 20 minutes at 5°C and the supernatant liquid decanted. This procedure was repeated two additional times for 70% and 100% levels of saturation.

Further purification was attempted on a 20 by 240 mm column packed with diethylaminoethyl cellulose (DEAE-cellulose) which had been equilibrated with 0.01 M acetate, pH 7.0 (Lange, Lee, and Merdinger, 1969). Four hundred mg of dialyzed and lyophilized material from the supernatant liquid resulting from the 70% level of saturation with ammonium sulfate was dissolved in 0.1 M acetate, pH 7.0, layered on the column, and eluted in a stepwise fashion with the solutions listed in Table 1. Protein elution was detected by noting the absorbance at 280 mu.

TABLE 1. Eluting solutions used in DEAE-cellulose column chromatography.

pH	Molarity of acetate	Mg lyophilized material recovered* (%)	Enzymes detected
7.0	0.01		
6.5	0.02	171 (43.2)	----
6.0	0.03		
5.5	0.04		
5.0	0.06		
4.5	0.08	9 (2.3)	----
4.0	0.10		
3.5	0.12		
3.0	0.25 (plus 1.0 M NaCl)	13.3 (3.4)	α-D-galactosidase β-D-fructofuranosidase trehalase

*396 mg present initially, total recovery 48.8%

Purification was also attempted using a batch fractionation procedure (4). Three hundred mg of dialyzed and lyophilized material from the 120,000 x g supernatant liquid was dissolved in 20 ml of 0.01 M phosphate, pH 7.8, and added to 1.5 gm wet weight of DEAE-cellulose which had been equilibrated in the same solution. The suspension was stirred for one hour at 5°C, filtered with suction, washed with 5 ml of the solution, and resuspended in

20 ml of the next eluting solution as presented in Table 2. The stirring, filtering, and washing was repeated with each of the succeeding eluants. The absorbance at 280 mμ was used as a measure of protein concentration.

TABLE 2. Eluting solutions used in the DEAE-cellulose batch fractionation procedure.

pH	Molarity of phosphate	Units of protein* (ml x A_{280})	Enzymes detected
7.8	0.01	183	---
7.0	0.02	22.5	---
6.0	0.03	3.5	---
5.0	0.05	2.9	---
4.0	0.5	22.6	{α-D-galactosidase β-D-fructofuranosidase
4.0	0.5 (plus 0.5 M NaCl)	15.5	---

*236 units present initially

Appropriate dialyzed fractions were assayed for carbohydrase activity using the following thirteen carbohydrates: inulin (Fischer Scientific Company, Fair Lawn, N. U.), cellobiose, gentiobiose, maltose, melezitose, methyl-α-D-glucoside, and stachyose (Mann Research Laboratories, N. Y., N. Y.), methyl-β-D-glucoside, sucrose, lactose and trehalose (Difco Laboratories, Detroit, Mich.). Assays were done in 0.10 M acetate, pH 5.5, at 37°C for 30 and 60 minute intervals. The concentration of the nonreducing sugars was 0.58 M, whereas lower concentrations of the reducing sugars were employed. The amount of reducing sugar was determined by the Folin-Wu method (Folin and Wu, 1920). The purification of the two enzymes were followed quantitatively using sucrose and trehalose as substrates. A unit of enzyme activity was defined as the amount of enzyme which hydrolyzed on μmole of carbohydrate per minute. Specific activity was stated as enzyme units per mg of protein. Protein was determined by the method of Lowry et al. (Lowry, Rosebrough, Farr, and Randall, 1951).

Michaelis constants were determined by the method of Lineweaver and Burk (1934). Sucrose and trehalose were the substrates in 0.1 M acetate, pH 5.5, incubated at 27°C for 60 minutes. These sugars were also used to determine pH optima by incubating 0.58 M concentrations in 0.1 M acetate at 25°C for 60 minutes.

RESULTS

Enzyme assay following differential centrifugation detected carbohydrases only in the 120,000 x g supernatant liquid. Those present in this fraction were estimated to be of 30-fold greater purity than the original homogenate. Of the carbohydrates tested, activity was detected with melibiose, raffinose, stachyose, sucrose, and trehalose. No activity was detected with cellobiose, gentiobiose, inulin, lactose, maltose, melezitose, methyl-α-D-glucoside, and methyl-β-D-glucoside.

Treatment with ammonium sulfate failed to precipitate any carbohydrases. The 100% of saturation supernatant liquid was 50% less active with sucrose (11% yield) and 50% more active with trehalose (33% yield) when compared to the 120,000 x g supernatant liquid.

DEAE-cellulose column chromatography gave no resolution of enzyme activities with all carbohydrases being eluted with the final solution (0.25 M acetate, 1.0 M NaCl, pH 3.0). The assays with sucrose and trehalose indicated the chromatography had increased the respective specific activities 50 and 60%.

The batch fractionation procedure with DEAE-cellulose gave some resolution. All detected carbohydrases were eluted with one solution (0.50 M phosphate, pH 4.0). This fraction could catalyze the hydrolysis of sucrose (400% increase in specific activity over the 120,000 x g supernatant liquid, 25% yield) and melibiose, but not trehalose.

The Michaelis constant using sucrose as a substrate was 0.017 M. An accurate determination of this constant with trehalose was not possible due to the limited sensitivity of the Folin-Wu method. It was estimated to be between 0.0002 and 0.0020 M. Both determinations were made in 0.10 M acetate, pH 5.5, at 37°C.

There was a broad pH optimum (90% of maximal velocity) from pH 3.6 to 5.0 with sucrose as the substrate. That for trehalose was between pH 4.6 and 5.9. Both optima were determined in 0.10 M acetate containing 0.58 M substrate concentrations at 25°C (Fig. 1 and 2).

CONCLUSION AND DISCUSSION

There are at least seven different enzymes that could have catalyzed the hydrolysis of the carbohydrates assayed (Table 3). Of these, inulase (International identification no. 3.2.1.7), α-D-glucosidase (3.2.1.20), β-D-glucosidase (3.2.1.21), and β-D-fructofuranosidase (3.2.1.26), and trehalase (3.2.1.28) were detected.

The failure of ammonium sulfate to precipitate carbohydrases was not unexpected since they tend to be glycoproteins.

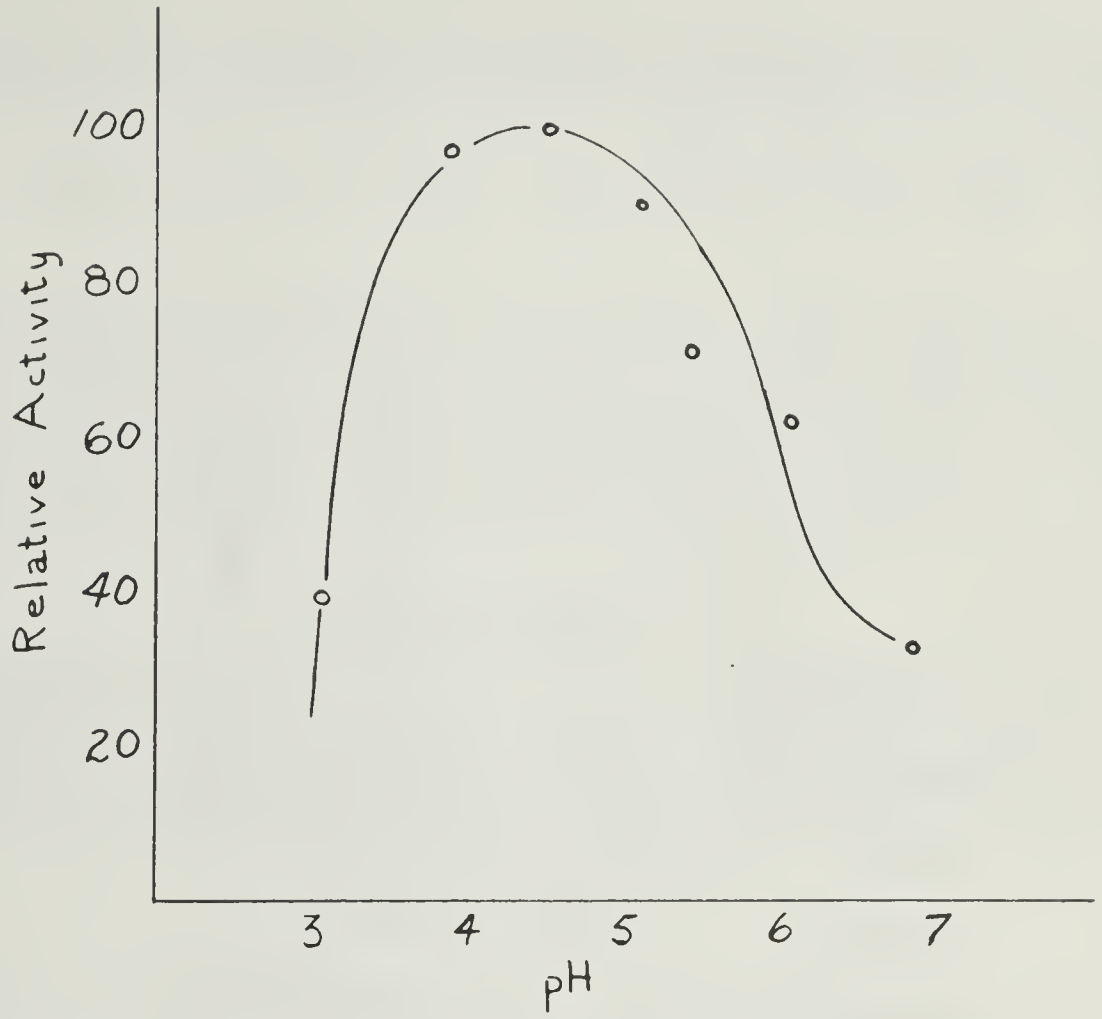

Fig. 1. pH curve with sucrose

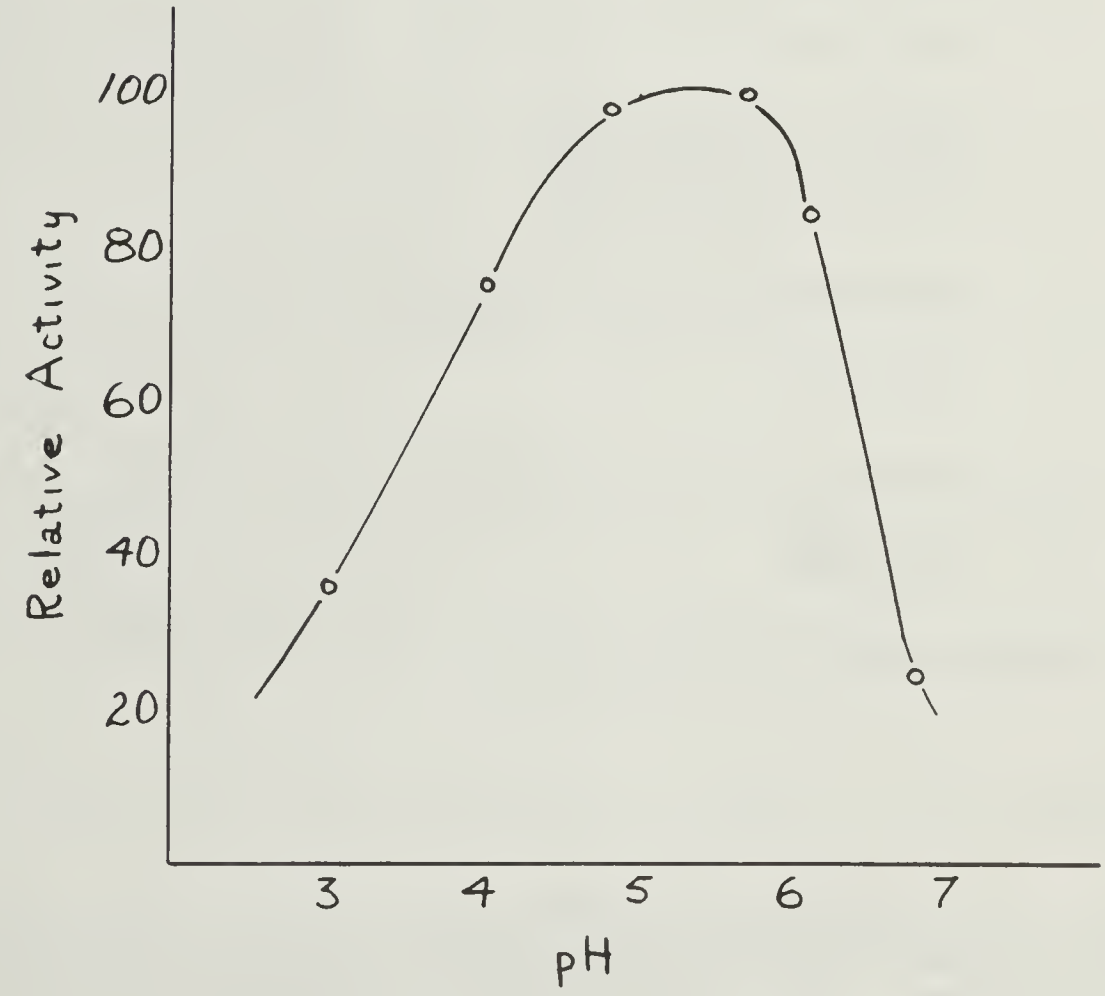

Fig. 2. pH curve with trehalose

TABLE 3. Carbohydrates assayed and their types of glycosidic linkages.

	α-D-glucoside	β-D-glucoside	α-D-galactoside	β-D-galactoside	β-D-fructofuranoside
1. cellobiose		X			
2. gentiobiose		X			
3. inulin	X				X
4. lactose				X	
5. maltose	X				
6. melezitose	X				X
*7. melibiose			X		
8. methyl-α-D-glucoside	X				
9. methyl-β-D-glucoside		X			
*10. raffinose	X		X		X
*11. stachyose	X		X		X
*12. sucrose	X				X
*13. trehalose	X				

*Carbohydrates hydrolyzed

The only resolution of enzymes noted was with the batch fractionatio procedure in which trehalase was removed from β-D-fructofuranosidase and α-D-galactosidase. The acidity and/or phosphate may have inactivated the trehalase.

The pH optima (about 5) and the Michaelis constants for the β-D-fructofuranosidase and trehalase were not very different when compared to those of other yeasts and molds (Andersen, 1960; Fischer and Kohtés, 1951;Merdinger, Lange, and Booker, 1971; Metzenberg, 1963; Panek and Souza, 1964).

The earlier study by Merdinger et al. with the yeast Pullularia pullulans achieved much greater purification of trehalase than the present one with Debaryomyces hansenii -- 800-fold versus 50-fold. The earlier purification was achieved using ammonium sulfate fractionation and DEAE-cellulose column chromatography with phosphate eluants (Merdinger, Lange, and Booker, 1971).

ACKNOWLEDGEMENT

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CYCLIC CARBONATES. III. THE SYNTHESIS, PHYSICAL AND CHEMICAL PROPERTIES OF VINYLENE CARBONATES

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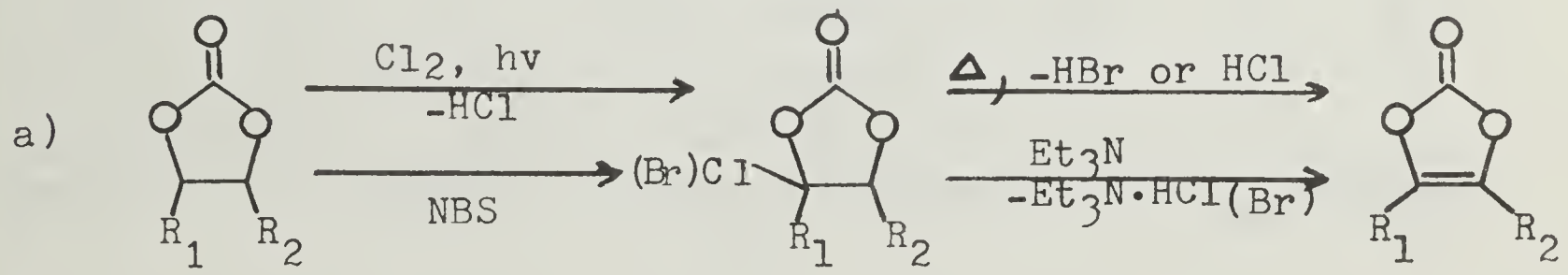
ABSTRACT

The synthesis and physical properties of four new vinylene carbonates (1,3-dioxol-2-ones) is described. They are dimethyl-, diphenyl-, methylphenyl- and methyl-(3-trifluoromethylphenyl)vinylene carbonate. General methods for the synthesis of vinylene carbonates are discussed along with their known reactions. A table enumerating the mode of synthesis, yield and physical properties of all known vinylene carbonates is presented.

In connection with our attempts to synthesize cyclopropanediols we required a series of substituted vinylene carbonates (IUPAC designation is 1,3-dioxol-2-ones). The synthesis and properties of several simpler members of this series have been reported previously. The parent compound, vinylene carbonate, was synthesized by Newman and Addor (1955) by triethylamine promoted dehydrochlorination of chloroethylene carbonate or by zinc dehalogenation of 1,2-dichloroethylene carbonate. Scharf, Droste and Liebig (1966) utilized the latter method to synthesize dichlorovinylene carbonate from tetrachloroethylene carbonate. Passing chloroehtylene carbonate over drierite at 250-60° (Johnson and Patton, 1960) and over salts and oxides of Groups I, II, VIIB metals at 300° (Holfermann and Springman, 1962) yields vinylene carbonate in fair to good yields also. Morris and Hubbard (1962) and Moss (1962) synthesized phenyl and methyl vinylene carbonates respectively by thermal dehydrohalogenation of the appropriately substituted chloroethylene carbonates. And phenylene carbonate (not formally a vinylene carbonate) can be synthesized by carbonylation of catechol using phosgene under basic conditions (see Org. Syntheses Coll. Vol. 4, 788, 1963). We have confirmed these syntheses and have extended the general methods to the synthesis of four new vinylene carbonates.

Successful synthesis of vinylene carbonates generally falls under three general methods:

a) halogenation--dehydrohalogenation.
b) halogenation-zinc dehalogenation and
c) carbonylation of enediols.



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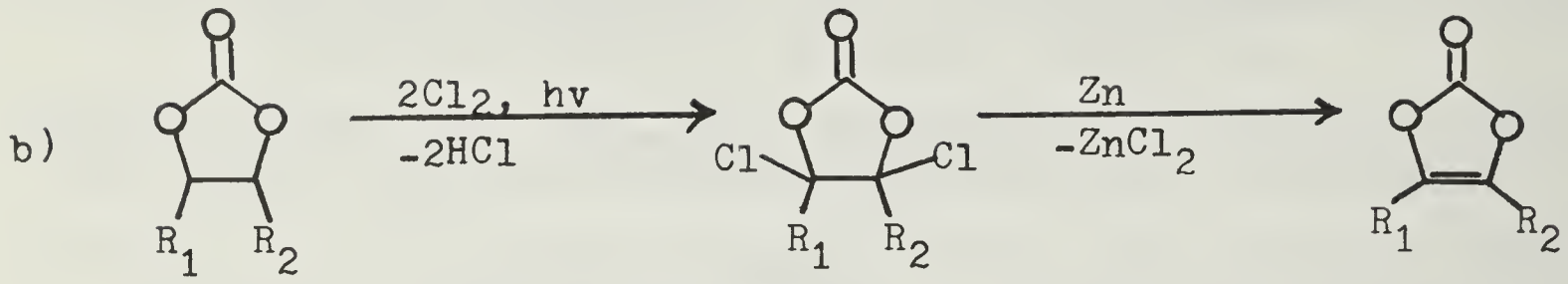

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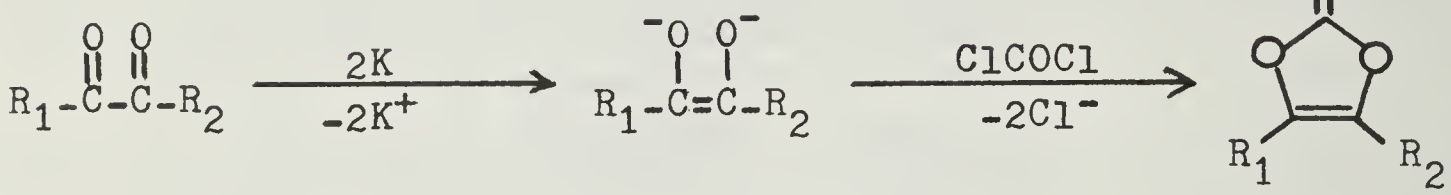

1 $R_1=R_2=H$

2 $R_1=CH_3$, $R_2=H$

3 $R_1=R_2=CH_3$

4 $R_1=C_6H_5$, $R_2=H$

5 $R_1=R_2=C_6H_5$

6 $R_1=CH_3$, $R_2=C_6H_5$

7 $R_1=CH_3$, $R_2=C_6H_4$ (3-CF_3)

8 $R_1=R_2=Cl$

Using these methods, we wish to report the synthesis and physical properties of four new vinylene carbonates, dimethylvinylene carbonate (3), diphenylvinylene carbonate (5), methylphenylvinylene carbonate (6) and methyl-(3-trifluoromethyl)phenylvinylene carbonate (7). This data along with the corresponding data for the previously synthesized vinylene carbonates is enumerated in table 1.

Table I. Vinylene Carbonates--Synthetic Methods and Physical Properties.

Compound	Method	% Yield	b.p.	m.p.	n_D	Reference
1‡†	a	72	73-4° (32 mm)	22.0°	1.4190 (25°)	Newman & Addor
1	a	36	63-5° (18 mm)	-	1.4190 (25°)	Johnson & Patton[a]
1	a	87	52° (8 mm)	-	-	Holfermann & Springmann
1	b	29	-	-	-	Newman & Addor
2	a	31	69° (17 mm)	-22.5°*	1.4264 (20°)	Moss
3	a	20-40	-	78-9°	-	*
4	a	60	110° (0.5 mm)	82-3°	-	Morris & Hubbard
4	b	36	-	-	-	ibid.
5	c	30	155° (0.4 mm)	75-6°	-	*
6	a	39	-	79-80°	-	*
6	b	4	107° (0.05 mm)	80.5-1°	-	*
7	a	43	-	75-6°	-	*
8	b	78	78° (64 mm)	-	1.4624 (25°)	*
8	b	-	39-40° (10 mm)	-	1.4602	Scharf, et al.

*this work

‡dipole moment u=4.57D (Dorriss, K. L., Britt, C.O., Boggs, J.E., J. chem. Phys. 44:1352 (1966).

In general vinylene carbonates undergo the classical chemical reactions of double bonds. Most interest to date has centered on the polymerization of vinylene carbonate and its utility in the cycloaddition reactions: [2+1] (carbene insertion), [2+2] (photocycloadditions), [2+3] (1,3-dipolar cycloadditions) and [2+4] (Diels-Alder Reactions). Vinylene carbonate is readily polymerized and then hydrolyzed to polyhydroxymethylene (Schaefgin and Field (1966). Copolymerization with a variety of other monomers had produced polymers with potential as semipermeable membranes. The synthetic interest in vinylene carbonates in cycloaddition reactions no doubt stems from the hydrolysis product, 1,2-diols. We (Breitbeil, et al., 1968) have synthesized a series of 1,2-cyclopropanediol cyclic carbonates by carbene insertion on vinylene carbonates ([2+1]-cycloaddition). The sensitized [2+2]-photocycloaddition of vinylene carbonate (Hartmann and Steinmetz, 1967; Hartmann, 1968) and dichlorovinylene carbonate (Scharf, 1968) to a variety of olefins to give 1,2-cyclobutanediol cyclic carbonates in good yields has been recently demonstrated. Vinylene carbonate can also dimerize under these conditions to give cyclobutane intermediates which hydrolyzed to 1,2,3,4-tetrahydroxycyclobutane (Hartmann and Steinmetz, 1967). The [2+3]-cycloaddition of vinylene carbonate to nitrile oxides (Desimoni, 1968) and subsequent hydrolysis has been shown to be a new route to 4-hydroxyisoxazoles. Perrini and Marxer (1963) found that treatment of vinylene carbonate with an amide and polyphosphoric acid at 165-170° gave the oxazole system. Vinylene carbonate also functions as a dieneophile in Diels-Alder reactions (2+4-cycloadditions), although somewhat reluctantly. Such dienes as cyclopentadiene and butadiene (Scharf, 1968), 2,3-dimethyl-1,3-butadiene, hexachlorocyclopentadiene, furan and cyclopentadiene (Newman and Addor, 1955), anthracene (Johnson and Patton, 1960b) and tetracyclone (Yates and Hyde, 1962) have been used. Vinylene carbonate hydrogenates with difficulty, but it and its derivatives add chlorine and bromine with ease (Newman and Addor, 1955). We have observed that vinylene carbonate adds hydrogen chloride to form monochloroethylene carbonate. We have also noted that the addition of chlorine to methylvinylene carbonate, under condi-conditions that do not restrict free radical processes, yields 4-chloro-5-methylene-1,3-dioxolan-2-one. With zinc chloride vinylene carbonate readily adds chlorodimethyl ether (Rieche, et al., 1965). Vinylene carbonate hydrolyzes to yield glycolaldehyde and a detailed study of the mechanism involved has been carried out (Saadi and Lee, 1966).

EXPERIMENTAL

Melting points were obtained using a circulating silicone oil bath and are uncorrected. Elemental analyses were carried out by Micro-Tech Laboratories, Inc., Skokie, Illinois. Infrared spectra were obtained from Perkin-Elmer 21 and 337 Infrared Spectrometers. Ultraviolet spectra were obtained from a Beckmann Model DK-2A spectrometer. The NMR spectra were obtained from a Varian A-60 spectrometer.

Dimethylvinylene Carbonate (3). To 58.0 g. (0.50 mole) of 2,3-butanediol cyclic carbonate (7) in 250 ml. of carbon tetrachloride in a conventional photolysis apparatus was added a chilled solution of 17.5 g. (0.50 mole) of chlorine in carbon tetrachloride. The mixture was cooled to 0-5° and photolyzed for 20 min. using a 450 watt high pressure mercury lamp in a quartz water-cooled insert. If desired the course of the reaction could be followed by observing the disappearance of the yellow color due to chlorine or the disappearance of two phases. Chlorinated ethylene carbonates are soluble in

carbon tetrachloride while ethylene carbonates are not. After degassing with nitrogen, the carbon tetrachloride was slowly distilled from the reaction mixture. Vacuum distillation gave three fractions, the first of which (b.p. 90-116° at 17 mm) was mostly 3 (15.5 g.) by NMR analysis; subsequent fractions were mostly starting material (b.p. 117-132° at 17 mm) and dichlorinated products. The total yield of 3 was 32% (NMR integration analysis). Crystalline 3 was separated by filtration from the distillate and recrystallized from carbon tetrachloride to give 9.7 g. of white solid, m.p. 78-79°. Carbonate 3 has an unusually high vapor pressure--several grams on a watch glass exposed to the air evaporated overnight. Attempted distillation of 3 caused fouling of glassware constrictures and vacuum tubing. The NMR spectrum (CCl_4, TMS std. showed a singlet at 2.01δ; IR (dilute CCl_4) absorptions at 1850 (s), 1830 (s), 1745 (m), 1230 (s), 1210 (s) and 1010 cm^{-1} (s); UV absorption (hexane) at 277.5 nm (ε_{max} 7.5).

Anal. Calcd. for $C_5H_6O_3$: C, 52.6; H, 5.3. Found: C, 52.45; H, 5.72.

Diphenylvinylene Carbonate (5). To 80 g. (0.38 mole) of benzil in 800 ml. of dry tetrahydrofuran was added 1393 g. of a 1.5% sodium amalgam. The reaction mixture turned bright orange. After refluxing 8 hrs., 45 g. (0.46 mole) of phosgene in cold tetrahydrofuran was added dropwise over a period of 30 min. After refluxing 24 hrs., most of the tetrahydrofuran was removed by distillation. About 800 ml. of slightly acidified water was carefully added and the mixture was extracted with ether, dried, solvent stripped and the residue distilled through a short path column. The desired product was collected at 155° (0.4 mm) and after recrystallization from heptane, 27 g. of white crystalline 5 was obtained, m.p. 75-6° (30% yield). The NMR spectrum (CCl_4, TMS std.) showed a singlet at 7.45δ; IR (dilute CCl_4) absorptions at 1825 (s), 1436 (m), 1235 (s), 1065 (s) and 755 cm^{-1} (s); UV absorption (hexane) at 294 nm (ε_{max} = 7.420), 218 nm (ε_{max} = 11,400), sh 236 nm (ε_{max} = 5,825).

Anal. Calcd. for $C_{15}H_{10}O_3$: C_1 75.6; H, 4.2. Found: C, 75.97; H, 4.21.

Methylphenylvinylene Carbonate (6). 3-Phenyl-2,3-propanedione was synthesized according to the procedure in Organic Synthesis (Vol. 23, 1 (1943)) was reduced with lithium aluminum hydride in the conventional way to obtain 1-phenyl-1,2-propanediol. Transesterification with diethyl carbonate (7) yielded a diastereomeric mixture of 1-methyl-2-phenylethylene carbonates in an overall yield of 41%. A weighed amount of this mixture (64.6 g., 0.32 mole) and 800 ml. of carbon tetrachloride was placed in the photoreaction vessel and cooled to 0°C. To this was added 33.4 g. (0.33 mole) of chlorine dissolved in cold carbon tetrachloride. With ice cooling and stirring the reaction mixture was irradiated for 20 min. with a 450 watt Hanovia-679A high pressure mercury lamp in which time it turned from yellow to colorless. After passing N_2 through for about 1 hr., the reaction mixture was slowly heated to reflux. A copious amount of hydrogen chloride was noted. The volume was halved by distillation and cooled. The desired crystallized product was collected by filtration and the entire process repeated four times to give after recrystallization from carbon tetrachloride, 22.0 g. of 6 as a white crystalline solid, m.p. 79-80°C. (39% yield). The NMR spectrum (CCl_4, TMS std.) showed singlets at 2.38δ and 7.42δ integrating 3:1; IR (dilute CCl_4) absorptions at 1830 (s), 1240 (s), 1192 (s) and 758 (s); UV absorption (hexane) at 271 nm (ε_{max} = 10,700), sh at 264 nm (ε_{max} = 10,250).

Methyl-(3-trifluoromethylphenyl)vinylene Carbonate (7). 3-Trifluoromethylpropiophenone was synthesized from 3-trifluoromethylbenzonitrile and ethylmag-

nesium bromide in the conventional way, and then converted to the 1,2-dione via the isonitroso derivative. Lithium aluminum hydride reduction and then transesterification using diethylcarbonate gave 1-methyl-2-(3-trifluoromethyl)-phenylethylene carbonate as a diastereomeric pair in overall 25% yield. In 200 ml. of dry carbon tetrachloride was dissolved 11.5 g. (0.0468 mole) of 1-methyl-2-(3-trifluoromethyl)phenylethylene carbonate and 8.9 g. (0.050 mole) of N-bromosuccinimide. This mixture, under an atmosphere of nitrogen, was irradiated in a Rayonet Srinivasan-Griffin Photochemical Reactor with eight RPR-3500 Å lamps for one hour. Succinimide was filtered and the solvent was removed under reduced pressure. The oily residue was heated in a flask with glass wool at 130° at 10 nm--Hg for 30 min. The pressure was reduced to 0.5 mm-Hg and the bromoethylene carbonate that had not dehydrobrominated was distilled at 95-105° (1.7 g.) The glass wool in the distillation flask was extracted two times with hot cyclohexane. On cooling and filtering, 4.9 g. of white crystalline 7 was obtained (48% yield based on consumed 1-methyl-2-(3-trifluoromethyl)phenylethylene carbonate). The NMR spectrum (CCl_4, TMS std.) showed singlets at 2.45δ and 7.68δ integrating 3:4; IR (dilute CCl_4) absorptions at 1840 (s), 1240 (s), 1130 (s); UV absorption (hexane) at 263 nm (ε_{max} = 24,600).

Anal. Calcd. for $C_{11}H_7F_3O_3$: C, 54.0%; H, 2.86%. Found: C, 53.27%; H, 2.93%.

ACKNOWLEDGMENT

We gratefully acknowledge the support of this work by the Research Corporation. Thanks are due Mr. Mahendra Patel for the ultraviolet spectra.

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EDITORIAL

The TRANSACTIONS of the Illinois State Academy of Science serves as a means of communication for the Scientific Community of our State. In this it has a double purpose: first, to keep us aware of on-going research, and secondly, to act as a repository of historically important facts about Illinois. The Editorial Board has accepted the challenge of ensuring that all suitable papers are published as quickly as possible. However we cannot ignore the financial problems that beset the Academy.

When it became apparent that the State appropriation could not cover the costs, the number of issues was curtailed. However, the Academy Council agreed with us that this was an unsatisfactory solution, and that every effort should be made to publish quarterly volumes of the TRANSACTIONS.

The question of how to distribute the cost of publication has received much attention by the Council and the Planning Committee. It has become obvious that it will be necessary to institute page charges in the near future.

In order to minimize these charges and also to meet our goal of reasonably rapid publication of all papers of interest to our membership, we are experimenting with a photographic reproduction process.

The Editorial Board will welcome comments on these matters.

Jacklyn B. Melchior
Editor

THE PRESIDENT'S PERSPECTIVE

The Illinois State Academy of Science first became known to me in 1961, though I have been dabbling in science in Chicago since 1947. Immediately I applied for membership. At the next meeting I presented a paper. Best of all I became acquainted with other scientists as individuals and with the organization of the Academy. I saw at once that my association with this group would promote my own teaching and research, and I gave the Academy my enthusiastic devotion. As Europeans say, I felt a "local patriotism", a sincere emotion of loyalty, and wanted to help all I could.

The chemistry section was my bailiwick. With others I worked hard on programs and memberships. It was deeply satisfying that I was instrumental in bringing together the Academy and all its advantages with many outstanding scientists several of whom have taken positions of leadership. Dr. George W. Beadle, the Nobel laureate, having wide organizational experience and astute analytical judgement has expressed in a letter to me some of the factors bearing on restrictions of growth of the Illinois State Academy of Science and has noted possibilities of developing the Academy into an even far more prestigious and influential body than it now is.

In recent years I have had the opportunity to serve the Academy by raising funds, money essential to our several programs of service and education. While corporations were solicited to support the Illinois State Academy of Science, the corollary was that corporate leadership became informed about the ISAS.

My mind's eye sees the Academy of the future as a stronger and more useful organization than ever before, widely recognized and respected among scientists and in the realm of science organizations. We have recently accepted a restricted number of members from four foreign countries.

The future growth of the Academy and our fine journal, TRANSACTIONS OF THE ILLINOIS STATE ACADEMY OF SCIENCE, depends on the members, individual scientists. Please be reminded that papers of merit contributed to the TRANSACTIONS quadruply serve. They serve the journal, the ISAS, the readers even to the end of the world, and very importantly the contributor himself. A journal with articles of merit is an essential raison d'être for a scientific academy. The TRANSACTIONS are your opportunity. My passion for a State Academy of Sceince in Illinois second to none in the USA is my kind of chauvinism.

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NUCLEAR DRY MASS AND AREA IN BINUCLEATE HUMAN BUCCAL MUCOSA CELLS

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Abstract

The means for nuclear dry mass (NDM), nuclear area (NA), and cell area (CA) for 30 binucleate human buccal mucosa cells were 55.3 x 10^{-12} g (55.3 pg), 66.4 x 10^{-8} cm^2, and 4833 x 10^{-8} cm^2, respectively. The NDM means for large (L) and small (S) nuclei were 62.2 and 48.4 pg, respectively. The NA means for L and S nuclei were 76.0 and 56.8 x 10^{-8} cm^2, respectively. The NDM and NA were not highly correlated (L, r = 0.52; S, r = 0.49). When the nuclei were studied for maturation changes using shape (round, oval, rod-pycnotic, and pycnotic), the binucleate cells were found to follow similar maturation patterns as mononucleate cells, although one of the nuclei in the binucleate cells undergoes the changes before the other.

Sandritter et al. (1958) reported the averages for cytoplasmic area (CA), cytoplasmic dry mean (CDM), nuclear area (NA), and nuclear dry mass (NDM) for human buccal mucosa cells to be as follows: CA, 4105 x 10^{-8} cm^2; CDM, 1941 pg; NA, 87 x 10^{-8} cm^2; and NDM, 55.5 pg. This was based on a study of 38 cells. Schiemer and Lauschke (1970) reported the average NDM of 800 human buccal cells to range from 39.9 to 53.3 pg. They cited other work in which the average of 5000 cells were about 39 to 43 pg. The sex and age of donors was not given. Pappelis (1972) reported NDM and NA of 80 of his cells (age 13) to be 73.1 pg and 83.1 x 10^{-8} cm^2, respectively. The agreement in average NA with that of Sandritter suggested possible age related NDM differences. Pappelis et al. (1973) and Pappelis and Pappelis (1972) reported low correlation coefficients between donor age and nuclear traits for male donors age 6 to 84. The NDM mean for 330 cells was 54.3 pg and for two groups of 210 cells the NDM means were 54.4 and 53.9 pg. The NA mean for 330 cells was 82.4 x 10^{-8} cm^2 and for two groups of 210 cells 80.7 and 77.5 x 10^{-8} cm^2. Lee et al. (1973) have data on parabasal (Pb), intermediate (I), rod-pycnotic (R-P), and pycnotic cells of the oral mucosa (cheek and upper lip). The means for cheek Pb cells were as follows: CA, 1713 x 10^{-8} cm^2; CDM, 1021 pg; NA, 69.5 x 10^{-8} cm^2; and NDM, 42.8 pg. When compared to Pb cells, changes in cheek cells through I, R-P, and P were as follows: CA is 230, 284, and 214%; NA is 128, 64, and 33%; and NDM is 145, 112, and 81%. CA and means for NDM and NA for the four cell types were highly correlated (r = 0.96) as were NDM and CA (r = 0.85) and NA and CA (r = 0.86). In another of their studies, when compared to Pb cells (CDM, 1021 pg; CA, 1482 x 10^{-8} cm^2), the CDM of I and P cells were 277 and 260% while the CA changes were 319 and 305%. The means for CA and CDM were

highly correlated (r = 0.99). The means for cell and nuclear indices for upper lip Pb cells were as follows: CA, 1591 x 10^{-8} cm^2; CDM, 768 pg; NA, 87.1 x 10^{-8} cm^2; and NDM, 46.7 pg. When compared to Pb cells, changes in lip cells through I and R-P were as follows: CA was 266 and 223%, CDM was 226 and 233%, NA was 122 and 51%, and NDM was 116 and 85%. Means for NDM and NA were highly correlated (r = 0.97) as were CA and CDM (r = 0.95). Thus, normal changes with respect to development in the human oral mucosa show that CA, CDM, NA, and NDM increase as cells pass from Pb to I cell types. Nuclear degeneration begins and NA and NDM decrease as cells pass from I through R-P to P cell types. The CA also decreases but CDM does not. Although binucleate cells were sometimes observed, they were not included in the studies.

This report represents NDM, NA, and CA measurements in binucleate buccal mucosa cells.

Materials and Methods

The NDM, NA, and CA were determined for 30 binucleate buccal mucosa cells (from seven smears) using quantitative interference microscopy methods previously described (Pappelis, 1972; Pappelis and Pappelis, 1972; Pappelis et al., 1973). The cells were from the senior author (female, age 26). Cells were classified by the cell maturation index suggested by Pappelis et al. (1973), based on the Impaired Cell Maturation Index (Niebergs, 1967). Nuclei were distinguished as being largest (L) or smallest (S) within the cell for comparative studies.

Results and Discussion

The NDM means for 30 binucleate cells were 62.2 pg (L) and 48.4 pg (S). The NA means for 30 binucleate cells were 76.0 x 10^{-8} cm^2 (L) and 56.8 x 10^{-8} cm^2 (S). The CA mean for the 30 cells was 4833 x 10^{-8} cm^2. The means for all nuclei were: NDM, 55.3 pg; and NA, 66.4 x 10^{-8} cm^2. The correlation coefficients for NDM and NA for the 30 L and S nuclei were: L, r = 0.54; S, r = 0.49; and combined data for L and S, r = 0.54. These are like those correlation coefficients reported by Lee et al., Pappelis (1972), Pappelis and Pappelis (1972), and Pappelis et al. (1973) for studies done on mature, mononucleate cells of the buccal mucosa. The NDM and NA means for L and S nuclei and the means for both nuclei are in close agreement with earlier reports for mononucleate cells which are given in the introduction. The CA means for these binucleate cells is like that reported by Sandritter et al. (1958), 4105 x 10^{-8} cm^2, and intermediate and rod-pycnotic cells reported by Lee et al. (1973), 4733 and 4857 x 10^{-8} cm^2, respectively.

The 60 nuclei in this study were classified by size and shape as round (R), oval (O), rod-pycnotic (RP), and pycnotic (P), following the system of Pappelis et al. (1973). The R nuclei were in parabasal cells, O and RP, in intermediate cells, and P in pycnotic cells. The following combinations of both nuclei were found: R-R, 4; R-O, 12; O-O, 9; O-RP, 2; RP-RP, 1; RP-P, 1; and P-P, 1. Since buccal mucosa cell maturation involves CA, NA, and NDM increases (parabasal to intermediate) followed by decreases in NA and NDM, we conclude that the binucleate cells follow a similar maturation pattern, although one of the nuclei in each cell undergoes the changes before the other. The only nuclei that appeared

to be alike in both NDM and NA were P-P.

We conclude that NDM, NA, and CA determinations are valuable data for use in cell maturation studies in mononucleate and binucleate cells of the buccal mucosa.

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This research was supported by Interdisciplinary Research in Senescence, a Cooperative Research Project, Southern Illinois University, Carbondale. We wish to thank C. C. Lindegren for the use of the Leitz Interference microscope (P.H.S. Training Grant No. 5 T01 GM 00593-08 from the National Institute of General Medical Science).

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THE FIRST RECORD IN ILLINOIS OF AELIA AMERICANA (HEMIPTERA:PENTATOMIDAE)

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ABSTRACT. -- The first record in Illinois of Aelia americana is presented.

While working with some undetermined Illinois specimens of Scutelleroidea housed in the Entomology Collection, Zoology Research Museum, I found five adults of Aelia americana Dallas (1851); this species has not previously been recorded from the state. The data for the specimens are as follows:

Jackson Co., Carbondale, 22 July 1963, 1♀, R. C. Heidinger Coll.; 21 April, 9 May, 18 May 1964, 3♀♀, F. Russell Coll.
Union Co., Pine Hills, 26 May 1961, 1♂, N. Berry Coll.

A. americana is an uncommon mid-western and western species. It ranges from Colorado and Arizona east to Missouri and Michigan and north into Canada (Torre-Bueno, 1939; Froeschner, 1941; McPherson, 1970). Since Missouri and Michigan are on either side of Illinois, the discovery of this insect in the state is not unexpected.

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Froeschner, R. C. 1941. Contributions to a synopsis of the Hemiptera of Missouri. Part 1, Scutelleridae, Podopidae, Pentatomidae, Cydnidae, Thyreocoridae. Amer. Midl. Nat. 26:122-146.

McPherson, J. E. 1970. A key and annotated list of the Scutelleroidea of Michigan (Hemiptera). Mich. Entomol. 3:34-63.

Torre-Bueno, J. R. de la. 1939. A synopsis of the Hemiptera-Heteroptera of America north of Mexico. Part I, Families Scutelleridae, Cydnidae, Pentatomidae, Aradidae, Dysodiidae and Temitaphididae. Entomol. Amer. 19:141-304.

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COMPARATIVE STUDIES OF ORGANIZED GUT-ASSOCIATED LYMPHOID TISSUE IN MAMMALS WITH DIVERSE FOOD HABITS. DISTRIBUTION, SIZE, AND ORGANIZATION OF PEYER'S PATCHES IN NEW WORLD BATS.

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ABSTRACT.-- The popular belief that herbivores (e.g., horses, sheep, cattle) have more abundant organized lymphoid tissue (Peyer's patches) in the small intestine than do carnivores (e.g., dogs, cats) was tested in insectivorous, piscivorous, carnivorous, nectivorous, frugivorous, and sanguivorous bats. No absolute correlation between numbers of Peyer's patches and food habits was apparent. However, these patches tended to be most abundant in nectar, fruit, and blood feeders, as compared to insectivorous, piscivorous and carnivorous kinds. Species of one genus of tropical insect feeders (Molossus) also had abundant Peyer's patches, whereas, all other tropical, as well as temperate, insect feeders had relatively few patches. Additionally, patches in the intestines of insect feeders, excluding Molossus, usually were more restricted in distribution than are those of plant and blood feeders. Peyer's patches varied considerably in dimensions among species, but patches usually were largest at the caudal end of the small intestine. Those species with the most numerous patches frequently, although not universally, possessed relatively greater total amounts of organized lymphoid tissue in the gut. The possible functional significance of variations in number and distribution of Peyer's patches in bats is discussed.

INTRODUCTION

Lymphoid tissue in the intestinal tracts of mammals occurs as loosely organized cells, or discrete assemblages containing lymphocytes, macrophages and reticular cells. The contributions of these organized assemblages, so-called Peyer's patches, to immunologic functions remain imperfectly understood.

Numerous studies (reviewed by Patzelt, 1936) have provided counts of Peyer's patches in several kinds of mammals, mostly domesticated or laboratory species. These studies led some workers, notably Ehlich (1946), to conclude that Peyer's patches are more abundant in herbivores (e.g., horse, rabbit) than carnivores (e.g., cat, dog). Additionally, Richter and Hall (1947) demonstrated that domestic Norway rats have more Peyer's patches than wild rats, and they suggested that these differences might be due to variations in diet. Differences in the number of Peyer's patches between species also have been proposed to relate possibly to such pathological conditions as the frequency of mammary tumors in mice (Kelsall, 1946), and tolerance for thiourea poisoning (Richter and Hall, 1947). None of the aforementioned studies examined variation in the

structure of Peyer's patches within or among species.

The studies reported here, which used a natural taxonomic assemblage of species of wild mammals, tested proposals which relate food habits and numbers of Peyer's patches. Bats provided an excellent resource for such studies, as their food habits are extremely diverse, yet are generally obligate for each species.

This report examined the distribution, abundance, and size of Peyer's patches, and their included lymphoid nodules, in the small intestines of selected New World bats.

MATERIALS AND METHODS

Intestinal tracts were preserved *in situ* in acid-formalin-alcohol, 10 percent formalin, or Bouin's fixative, and stored in 70 percent alcohol. In most cases the animals were fasted for a minimum of 10 hours prior to fixation. Most specimens were prepared as skins and skulls, and are housed in the Museum of Natural History, the University of Kansas.

Sectioning of tissues was accomplished using standard wax embedding procedures. Tissues were stained with Harris' haematoxylin and eosin, or Azure A-eosin B.

The values for "area occupied by Peyer's patches" in Table 1 were obtained by multiplying breadth times length to achieve area in square millimeters. Because not all patches were precisely rectangular, the values shown are approximate.

The values for "average midlongitudinal surface area" of individual nodules recorded in Table 2 were determined as follows. Since the nodules were symmetrical, pyramid-shaped objects, the surface area of a midlongitudinal section could be computed using the formula for area of an isosceles triangle. Therefore, the values in Table 2 represent "indexes" of nodular size and not total surface area. Fewer species are represented in Table 2 than in Table 1 because not all nodules were fixed adequately for histological observation. Therefore, these nodules were considered unsuitable for measurement.

A total of 75 specimens (35 species) were examined. The number of specimens examined of each species appears in parentheses following "number of patches" in Table 1. Due to the small samples of species examined conclusions drawn must be considered tentative, until larger samples become available.

RESULTS

Most species of bats had relatively few Peyer's patches compared to other kinds of mammals that have been studied. The results of counts of Peyer's patches are recorded in Table

1. Fruit eaters, along with several probable nectivores (Anoura, Lichonycteris and Glossophaga), one blood feeder, and insect feeders of the genus Molossus, tended to have the greatest number of Peyer's patches. This is a trend only, because intraspecific variation was extensive in the fruit-eating kinds. The fewest patches (one to three) were observed in carnivorous and most insectivorous kinds. Temperate species of the family Vespertilionidae usually had three patches. Probable omnivores, such as Phyllostomus discolor and P. hastatus often had few, but extremely large patches. There was no apparent relationship between the sex of an animal and the number of patches.

The relative amount of lymphoid tissue often was a function of the number of Peyer's patches. However, variation in the size of patches was extensive and exceptions to the above were frequent. Surface area of the intestine occupied by lymphoid tissue appears in Table 1. The large bats such as Phyllostomus, Artibeus, Chrotopterus, and Noctilio had more of this organized lymphoid tissue than most smaller ones, however, a consistent relationship did not occur. For example, Eptesicus fuscus, a large temperate insect feeder, frequently had less lymphoid tissue in the gut than species of the smaller Myotis. Although temperate forms sometimes had slightly smaller nodules during torpor than when active (personal observation), hibernation apparently had little effect upon the number of nodules. In contrast, the small to medium-size species of Molossus, all insect feeders, consistently possessed large numbers of extremely well developed lymphoid patches.

Nevertheless, it is apparent from the results in Table 1 that fruit-eating and tropical flesh-eating and omnivorous species had relatively larger amounts of organized gut lymphoid tissue than do most tropical as well as all temperate insect eaters.

Most Peyer's patches were in the lower one-half to one-third of the small intestine. Only a single location possessed a patch in all species. This patch was at, or extremely near, the ileocolonic junction and always was the most caudal one. This patch frequently was larger than others within the animal. Also, it usually was structurally different from other patches because it protruded from the intestinal wall as an ampulla or vestibule and was, therefore, easily observed macroscopically.

Patches never were observed in the large intestine, and rarely were within the superiormost one-third of the intestine in any but fruit- and nectar-feeding kinds, and Molossus. Patches were in the duodenum in only a few species. These included Anoura geoffroy, Lichonycteris obscura, Desmodus rotundus, and all species of Molossus. Lymph nodules at the

TABLE 1

Numbers of and total surface area occupied by Peyer's patches in selected species of bats

SPECIES	#PATCHES	*N	SURFACE AREA (mm^2) ($\bar{X}$)	FOOD
Rhynchonycteris naso (E)	6	2	6.5	insects
Noctilio leporinus (No)	3	2	58.9	fish
Mormoops megalophylla (Mr)	3	1	12.3	insects
Pteronotus parnellii (Mr)	1-3	3	28.5	insects
Chrotopterus auritus (P)	2	1	64.0	small animals
Micronycteris megalotis (P)	3	1	3.3	insects
Phyllostomus discolor (P)	3-4	4	35.8	fruit, insects
P. hastatus (P)	4	2	99.5	fruit, small animals
Anoura geoffroyi (P)	9	1	18.3	nectar, pollen
Choeroniscus godmani (P)	4	1	6.5	nectar, insects
Glossophaga soricina (P)	3-7	2	37.3	nectar, insects
G. commissarisi (P)	3	2	15.5	nectar, insects
Lichonycteris obscura (P)	8	1	12.0	nectar
Carollia perspicillata (P)	3	1	25.3	fruit, insects?
Sturnira ludovici (P)	5	1	31.3	fruit
S. lilium (P)	5-12	4	50.5	fruit
Artibeus lituratus (P)	4-9	2	23.1	fruit
A. jamaicensis (P)	4-10	6	46.5	fruit
Chiroderma villosum (P)	3-6	2	8.0	fruit
Uroderma bilobatum (P)	4-7	3	10.1	fruit
Vampyrodes major (P)	2-9	3	16.5	fruit
Desmodus rotundus (P)	5-8	2	27.4	blood
Natalus stramineus (Na)	1	1	5.3	insects
Eptesicus fuscus (V)	1-3	2	5.8	insects
Nycticius humeralis (V)	2-3	4	10.0	insects
Myotis keeni (V)	3	4	12.0	insects
M. lucifigus (V)	3	6	12.0	insects
Lasiurus cinereus (V)	3	1	8.5	insects
Lasionycteris noctivigans (V)	3	1	7.0	insects
Plecotus townsendi (V)	3	3	5.5	insects
Rhogessa parvula (V)	2	1	4.3	insects
Molossus ater (Mo)	9-10	2	84.1	insects
M. sinaloae (Mo)	7	1	61.3	insects
M. molossus (Mo)	5	1	30.5	insects
M. aztecus (Mo)	6	1	26.0	insects

E = Emballonuridae; Mo = Molossidae; Mr = Mormoopidae;; Na = Natalidae
No = Noctilionidae; P = Phyllostomatidae; V = Vespertilionidae

*N = specimens examined

TABLE 2

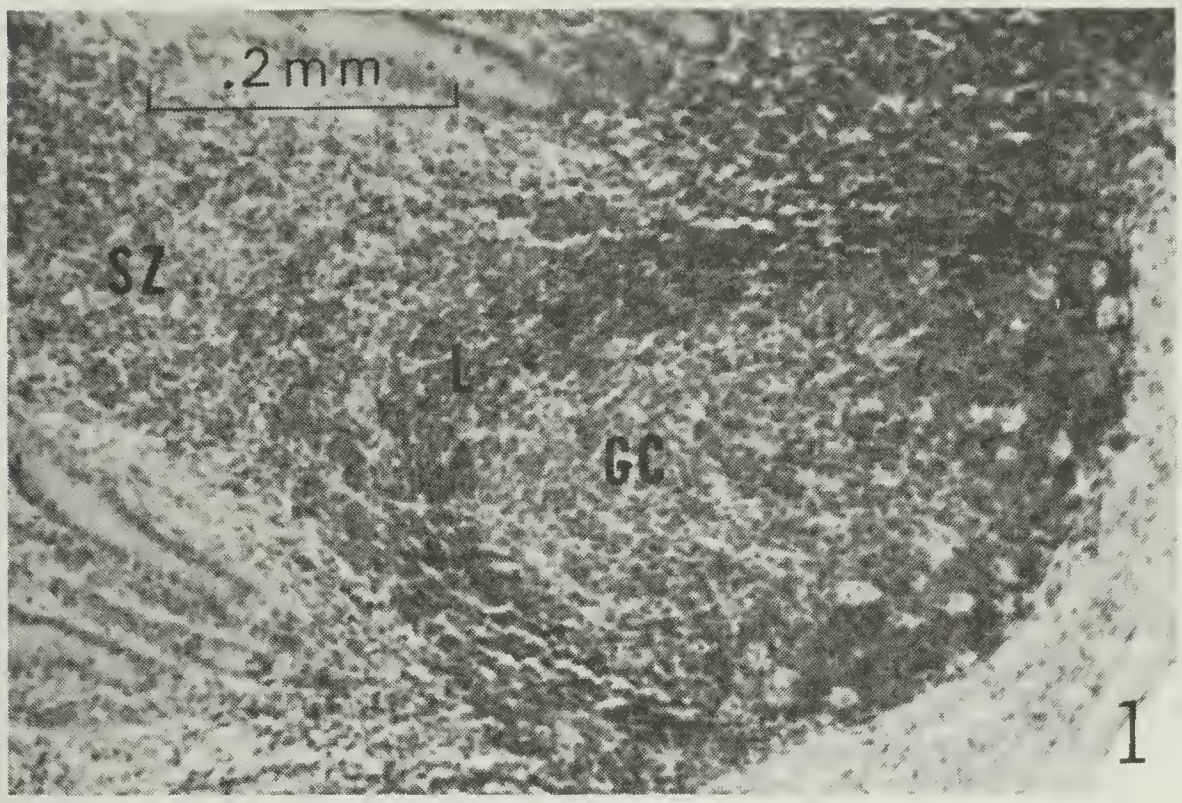
Surface areas of midlongitudinal sections of nodules within Peyer's patches in selected species of bats

SPECIES	$\bar{X}_a$ (mm^2) (caudalmost patch)	N_a	$\bar{X}_b$ (mm^2) (cranialmost patch)	N_b
Noctilio leporinus	.21	3	.16	2
N. labialis	.12	4	.12	2
Pteronotus parnellii	.13	4	.14	4
Chrotopterus auritus	.17	4	.15	3
Phyllostomus discolor	.20	6	.17	6
P. hastatus	.46	2	---	-
Anoura geoffroyi	---	-	.07	3
Glossophaga soricina	.11	1	.12	3
G. commissarisi	.16	5	.08	3
Carollia perspicillata	.11	2	.16	4
Sturnira lilium	.33	5	.13	3
Artibeus lituratus	.16	3	---	-
A. jamaicensis	.26	2	.15	4
Chiroderma villosum	.03	3	.03	1
Uroderma bilobatum	.24	3	.33	3
Vampyrodes major	.20	3	.16	2
Desmodus rotundus	.08	1	.08	2
Eptesicus fuscus	.08	2	.04	3
Myotis keeni	.06	4	.05	5
Nycticieus humeralis	.08	4	.09	3
Molossus ater	.26	1	.17	2
M. aztecus	.27	1	.15	2
M. molossus	.21	2	.19	2
M. sinaloae	.17	2	.08	3

$\bar{X}$ = mean of midlongitudinal surface area of nodules within selected species of bats

$$\bar{X} = \frac{\sum (\frac{1}{2}b \times h)}{N}$$

b = width of nodules at base
h = maximum height of nodule
N = number of nodules measured/patch



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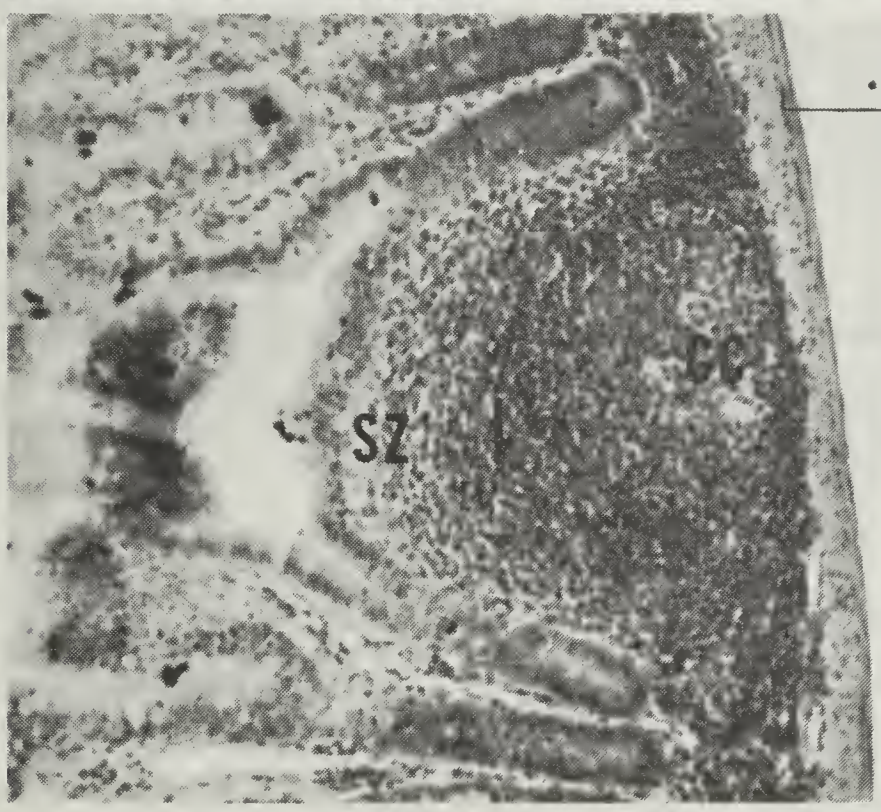

2

Fig. 1. A lymph nodule within a typical Peyer's patch of Chrotopterus auritus, a large tropical carnivorous bat: GC = germinal center, L = zone of small lymphocytes, SZ = subepithelial zone.

Fig. 2. A lymph nodule within a typical Peyer's patch of Myotis lucifigus, a small temperate insect eater. Note the considerably smaller size of the nodule compared with that of figure 1. For an explanation of symbols see figure 1.

gastroduodenal junction, an unusual condition, occurred in all species of Molossus.

The most restricted distribution of nodules was in insect-feeding genera (excluding species of Molossus), as nodules usually were present only in the lower one-third or one-half of the intestine. These included Micronycteris, Natalus, Lasionycteris, and most specimens of Pteronotus, Eptesicus and Myotis.

The areas enclosed by midsagittal sections of individual nodules were estimated to provide an index of nodular size. Average area, with numbers of nodules measured, is recorded in Table 2. Values are included for the most cranial patch ($\bar{X}_a$) and most caudal one ($\bar{X}_b$). Large bats (e.g., Noctilio, Chrotopterus) often had larger nodules (Fig. 1) than smaller bats (e.g., Carollia, Myotis (Fig. 2)), however, a consistent relationship was not apparent. Bats, with numerous patches or few but especially large patches also possessed large nodules. Only three species (Vampyrodes major, Uroderma bilobatum, and Glossophaga commissarisi) had relatively large nodules, but little total lymphoid tissue. These results suggest that major differences in amounts of gut associated lymphoid tissue in bats were primarily a function of individual nodular development.

Temperate insect feeders such as Myotis and Eptesicus always possessed extremely small nodules, whereas, the species of Molossus consistently revealed large ones. Among fruit-eating species only Chiroderma had small nodules. The only vampire examined, Desmodus rotundus, also possessed small nodules.

In addition to distinctive variation among species in the size of nodules considerable variation usually was present within each bat. Nodules almost always were largest near the inferior (ileum) end of the small intestine and smallest when nearest the stomach (see $\bar{X}_a$ and $\bar{X}_b$ in Table 2). The differences between extremes in size are greatest in those species with the largest nodules (i.e., the largest bats).

DISCUSSION

The food of most bats consists of either plant or animal material, but rarely both. Fleming et al. (1972) has documented the obligate insect-eating habits of the tropical species Rhynchonycteris naso, Noctilio labialis, Mormoops megalophylla, Pteronotus parnellii and several species of Molossus in Costa Rica. Although Goodwin and Greenhall (1961) said Micronycteris megalophylla is a fruit eater (based on a study of one specimen), it probably includes many insects in its diet as do some other species in this genus (Wilson, 1971). The dentition of Micronycteris is said to be that of an insect eater (Walker, 1964). The fish-eating habits of Noctilio leporinus are well

known (Bloedel, 1955) as are the carnivorous habits of Chrotopterus auritus (Constantine, 1966; Tuttle, 1967). The eating of fruit pulp, juices, and seeds by many phyllostomatids including species of Carollia (which may take some insects), Sturnira, Artibeus, Chiroderma, Uroderma and Vampyrodes is documented in Fleming et al. (1972), Arata et al. (1967) and Goodwin and Greenhall (1961). Phyllostomus discolor and P. hastatus are omnivorous, but they consume large quantities of fruit in addition to some small animals (see Arata et al., 1967; Goodwin and Greenhall, 1961; Greenhall, 1966). Phyllostomatids of the subfamily Glossophaginae are primarily nectivorous and pollenivorous (Alvarez and Quintaro, 1969). Some species of Glossophagines, for example G. soricina (Arata et al., 1967) and Anoura (Alvarez and Quintaro, 1969), take some insects. The insectivorous habits of many temperate North American bats have been studied by Ross (1967). These animals consume large quantities of flying ants, beetles, moths and mosquitoes. The vampire Desmodus rotundus is an obligate sanguivore which takes occasional insects.

The contribution of gut associated lymphoid tissue to the immunologic response in mammals has not been precisely determined. Many workers, including Henry et al. (1970), suggested that Peyer's patches may require interactions with other cell types, perhaps epithelial, to contribute to the immune response. Fichtelius (1968) has suggested that the gut epithelium is a "first level" lymphoid organ, and that it contributes to the immune response by stimulation of lymphocytes to produce immunoglobulins.

The ability of intestinal contents to stimulate antibody production in the gut, or elsewhere, presently is being disputed (see Cooper et al., 1967). Nevertheless, it has been demonstrated that Peyer's patches have greater cell turnovers in non germ-free than in germ-free mice. This indicated that the presence of a bacterial flora, especially in the ileum, does modify lymphoid as well as epithelial portions of the mucosa (Abrams et al., 1963). Also, Pollard and Sharon (1970) reported activation of Peyer's patches in germ-free mice via absorption of Salmonella- produced antigen into the circulation from the intestinal lumen. Distinctive increase in the size of nodules accompanied this activation. Clark (1963) suggested that lymphoid nodules in the gut may act as "marshalling grounds" for cells capable of inactivating endotoxins in the intestine.

No clear relationship between diet and distribution of Peyer's patches within the gut was observed in bats. However, lymphoid tissue tends to be most abundant in the ileum, and in some species, especially temperate insect feeders, it usually occurs only there. Perhaps bacterial populations which contribute to food assimilation are greatest in tropical species, especially fruit and nectar feeders.

Differences in the abundance and distribution of Peyer's patches may be the result of differences in amounts of antigenic stimulators such as pollen or other plant-related sources of foreign protein. The relatively extensive development of individual patches and nodules, as well as the pronounced increase in size of nodules toward the large intestine in tropical species, especially fruit- and nectar-feeding kinds, are possibly a function of high concentrations of pollen or bacteria.

Lymphoid tissue in the cranial region of the intestine in those kinds which injest principally fruit juices, nectar, or blood suggests a relationship between liquid food and the abundance and/or broad distribution of such tissue. Relatively short intestinal transit time in bats (Klite, 1965), a likely occurrence with most liquid food material, would allow exposure of undigested, potentially antigenic materials to the intestinal mucosa. These conclusions are tentative, and await review or support from studies of other groups of mammals.

The Peyer's patches of Molossus, which are both distributionally and quantitatively extensive, present a unique condition within an insect-eating group. It is of particular interest that Klite (1965) found the bacterial flora in the intestinal contents of Molossus major to be greater than that of two other kinds studied (one species of fruit-eating Carollia and one species of the insect-eating Chilonycteris). Relatively high bacterial populations perhaps lead to an extensive response by gut-associated lymphoid tissue in Molossus, a unique condition among insect feeders.

No relationship between the frequency of Peyer's patches and intestinal length, sex, season, reproductive state, or relatively sizes of roosting aggregations could be established.

Finally, the consistent presence of a single unusually distinctive patch at or near the junction of the intestine and colon is noteworthy when compared to some other kinds of mammals. A similarily placed patch is known to occur at the site of the ileocaecal valve in several mammals; for example, in opossums (Azzali and DiDion, 1965), sea lions (Murie, 1874) and manatees (Beddard, 1897). Perhaps the presence of a similar, but often evaginated, patch in all bats studied marks the position of a one-time intestinal caecum or bursa, or one that is being evolved. A histological study of Peyer's patches, to be presented in a forthcoming paper, should help to determine if the caudalmost Peyer's patch is indeed unique.

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A RELICT POPULATION OF THE FOUR-TOED SALAMANDER HEMIDACTYLIUM SCUTATUM (SCHLEGEL) IN JERSEY COUNTY, ILLINOIS

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ABSTRACT: The discovery of a relict population of the four-toed salamander Hemidactylium scutatum (Schlegel), in Jersey County, Illinois is reported. Notes on habitat, breeding and size are included.

COLLECTION RECORD

Neill (1963) given the range of the four-toed salamander, Hemidactylium scutatum (Schlegel), as "..fairly continuous from extreme southern Maine, extreme southern Quebec, extreme southern Ontario and northern Wisconsin, southward to the Fall line in North Carolina, South Carolina, Georgia, Alabama, and Tennessee; presumably disjunct populations occur in Nova Scotia, Missouri, Arkansas, Louisiana, Georgia and Florida." In Illinois, Hemidactylium scutatum has been known from only 18 specimens -- Cook County (12), Lake County (3), Ogle County (3). All but the Ogle County specimens (18 October 1964) were collected before 1933 (Lynch, 1965). Here I report a second relict population in Jersey County, west-central Illinois, approximately 200 miles southwest of Ogle County locality and separated from it by a broad expanse of unsuitable prairie habitat. The Jersey County site is 76 miles north of the locality of the only published Missouri (Ste. Genevieve County) record (Smith, 1956) and 101 miles northeast of the locality in Reynolds County, Missouri for two specimens in the Southern Illinois University at Edwardsville collection, collected 8 May 1964 by M. O. Lamble and D. Hinton. The Missouri populations are separated from the Jersey County population by the Mississippi River. Geographic separation of the Jersey County population from all other known populations suggests that it is a relict.

SITE DESCRIPTION

The first Jersey County specimen (SIUE 164) was taken 4 April 1967 from inside a concrete spring box at the bottom of a rock creek bed. The specimen was clinging to moss about a foot above the water. No other specimens were found though the immediate area was searched. On 4 May, four more H. scutatum were discovered in a ravine about one mile from the first locality. These individuals were under rocks at the waterline of a leaf-filled pool (3x4 ft.), fed by a cold-flowing spring. Three specimens were under a rock with two nests of eggs, the other about three feet away (SIUE 165, 166, 167). Three of these specimens and one nest of eggs were collected. One female and a nest of 62 eggs were left undisturbed. Collecting at other than the nesting site was greatly hampered by 3-5 feet of leaf litter. Other salamanders may have been present around the pool, but I preferred to leave the habitat undisturbed rather than search further. The surrounding woods consisted of oaks, hickories and hard maples. Some of the oaks were larger than 3 feet in diameter, and the area was littered with large fallen trees.

This is the first record of H. scutatum nests in Illinois, the first record of nests near cold-flowing springs, and the first report of nests on rocks and soil. Wood (1955) reported nests in mosses, sedges, hepatics, under loose bark, in mounds of pine needles and in rotten wood near bog streams, ponds, seepage springs, and stagnant pools in association with deciduous or coniferous woods. Another record of specimens collected near a cold spring is that of Smith (1956) from Ste. Genevieve County, Missouri. This population would probably breed in the spring. These observations suggest that H. scutatum had adapted to breeding in cold spring water in these western relict populations.

EXPERIMENTAL

The three specimens and the eggs from the second Jersey County locality were placed in a glass aquarium in a constant temperature unit (19°C) and maintained until 3 June. During the night of 4 May and early morning of 5 May, one of the salamanders deposited additional eggs on the aquarium glass and on the leaves in the aquarium. The next morning a few more eggs were discovered. On 23 May a single hatchling was discovered, apparently from one of the wild-collected eggs. Five eggs hatched, but an attempt to raise the hatchlings was unsuccessful.

DESCRIPTION OF SPECIMENS

The three females were preserved on 3 June. Measurements and counts on the four specimens were taken immediately after drowning (Table 1). Three had bold, black spots on the venter, but SIUE 166 had a marbled venter with sub-equal black and white areas. This marbled venter pattern has not been previously reported. The largest previously reported specimen was 100.0mm in total length (Lynch, 1965); SIUE 164 was 107.1mm total length making it a new size record. Comparison of lengths of the four Jersey County specimens with those of other reports (Table 2) suggests that H. scutatum reaches its greatest size in the Illinois relict populations.

TABLE 1

Measurements and Counts of Hemidactylium scutatum collected in Jersey County, Illinois

Specimen	Sex	Total Length (mm)	Snout-vent Length (mm)	Costal Grooves	Costal Folds Between Adpressed Limbs
SIUE 164	F	107.1	47.3	13	3.0
SIUE 165	F	98.1	46.3	12	2.5
SIUE 166	F	94.3	43.0	12	2.5
SIUE 167	F	92.7	40.5	12	2.0

TABLE 2

Mean total length (mm) of various samples of
Hemidactylium scutatum females

Locality	Number	Mean
Southern Michigan (Blanchard and Blanchard, 1931)	-	74.7
	-	83.7
	-	74.1
Central New York (Bishop, 1941)	-	70.9
Virginia (Wood, 1953)	204	78.4
Jersey County, Illinois	4	98.0

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A FORTRAN IV COMPUTER PROGRAM TO TABULATE AND GRAPH MICRO-CLIMATIC DATA

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Abstract--A computer program is described which facilitates the tabulation and presentation in graphic form the micro-climatic parameters of temperature, relative humidity, solar radiation, and precipitation.

INTRODUCTION

Researchers in the natural sciences are often confronted with the need to collect, assimilate, reduce, tabulate, and graph large amounts of micro-climatic data in support of the major objectives of their research undertakings. Digital computers provide the technology to save large amounts of time and expense, thus freeing the investigators for efforts more central to their theme. The recent application of line plotters and their attendant software to computer systems has added another dimension to the compute and list capabilities available in the past (Mitchell and Anderson, 1969).

COLLECTION OF FIELD DATA

The Springer-Sangamon Environmental Research Program is a major interdisciplinary research program relating to the ecological consequences resulting from the construction and operation of the Oakley Dam and Reservoir on the Sangamon River (Bell, 1972). To facilitate the joint collection of environmental data, seven first-class weather stations have been constructed in forested intensive study sites within the Upper Sangamon River watershed. Each weather station measures and records temperature, relative humidity, precipitation, and solar radiation. Other parameters measured, but not described in this paper, include wind distance and soil temperature from three soil depths. Data recorded from these stations would prove burdensome without a system of data management.

Data collected weekly from weather stations are transferred to a station data card to facilitate key punching (Fig. 1). Mean daily temperature and relative humidity values are determined before key punching data on Hollerith cards. Wind distance is punched, but the data is not used in the following program. The punched Hollerith cards should be checked against the station data card before execution of the program.

THE COMPUTER PROGRAM

The computer program is written in the FORTRAN IV language for the University of Illinois IBM 360/75 computer and uses the attached CalComp

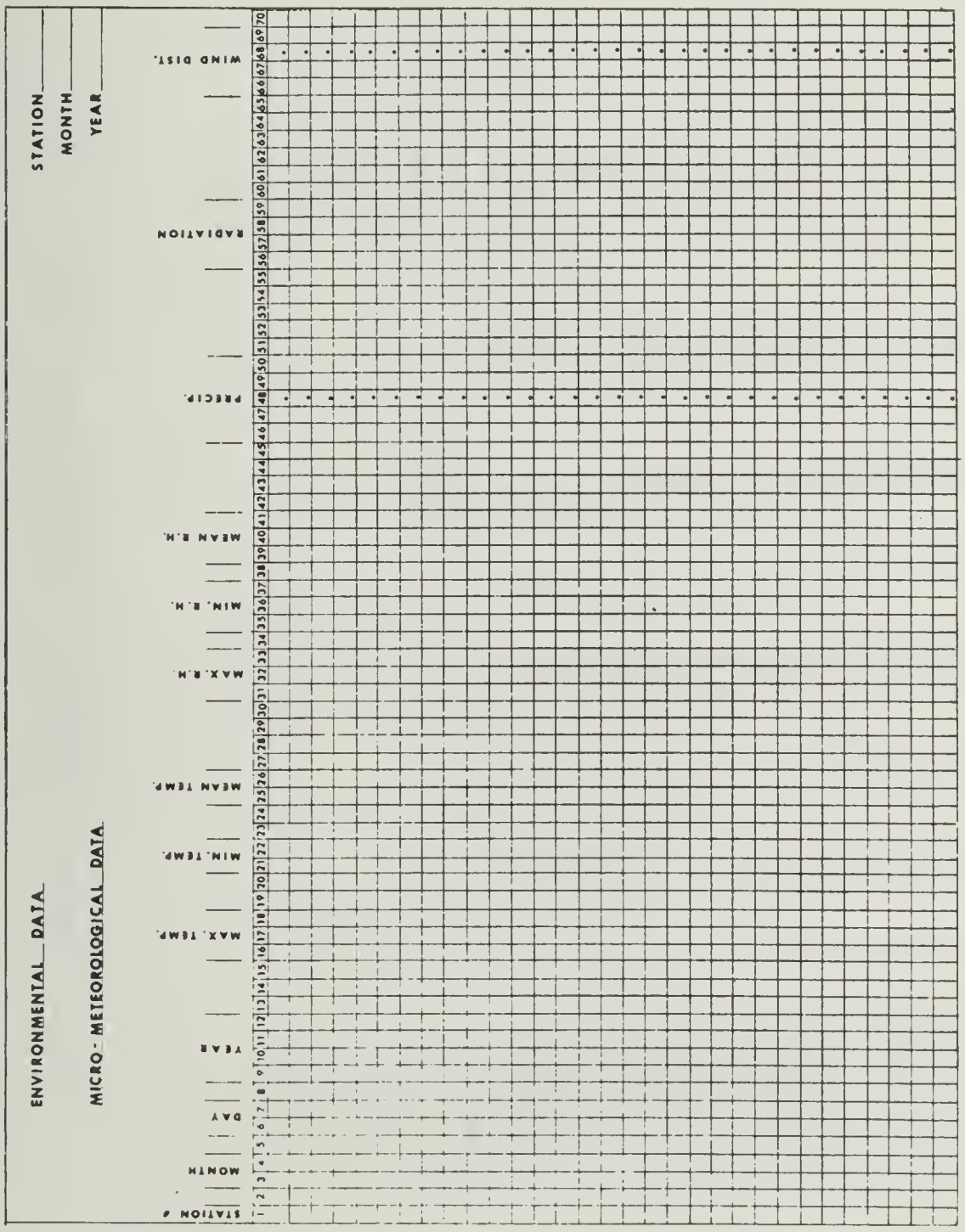

Fig. 1. Weather station data card. Provides record of data from instrument charts and provides key punching locations for Hollerith cards.

SPRINGER-SANGAMON ENVIRONMENTAL RESEARCH PROGRAM

MICRO-METECROLOGICAL DATA

WEATHER STATION NO.1 DATE= 4 - 1972

DATE	TEMPERATURE MAX	TEMPERATURE MIN	TEMPERATURE MEAN	RELATIVE HUMIOITY MAX	RELATIVE HUMIOITY MIN	RELATIVE HUMIOITY MEAN	PRECIP.	RADIATION
4 - 1 - 1972	35	27	31	97	65	81	0.23	156
4 - 2 - 1972	40	31	35	95	49	72	0.01	236
4 - 3 - 1972	43	30	36	98	74	86	0.25	108
4 - 4 - 1972	44	25	34	96	39	68	0.0	384
4 - 5 - 1972	62	36	49	88	30	59	0.0	339
4 - 6 - 1972	78	43	60	100	44	72	0.0	290
4 - 7 - 1972	48	22	35	100	67	84	0.49	89
4 - 8 - 1972	37	20	28	87	49	68	0.0	390
4 - 9 - 1972	51	28	40	96	42	69	0.0	384
4 - 10 - 1972	70	54	62	95	36	65	0.0	276
4 - 11 - 1972	68	48	58	100	33	66	0.98	295
4 - 12 - 1972	67	49	58	100	86	93	0.0	65
4 - 13 - 1972	76	47	61	94	45	69	0.03	371
4 - 14 - 1972	70	43	56	97	61	79	0.02	230
4 - 15 - 1972	66	49	57	100	77	88	0.0	143
4 - 16 - 1972	56	39	47	99	66	82	0.73	158
4 - 17 - 1972	72	50	61	80	36	58	0.0	221
4 - 18 - 1972	76	44	60	98	33	65	0.0	421
4 - 19 - 1972	72	57	64	100	53	76	1.91	208
4 - 20 - 1972	58	44	51	98	77	87	0.0	139
4 - 21 - 1972	57	44	50	100	82	91	0.81	67
4 - 22 - 1972	59	43	51	88	54	71	0.01	382
4 - 23 - 1972	53	39	46	95	51	73	0.0	293
4 - 24 - 1972	50	38	44	98	56	77	0.0	180
4 - 25 - 1972	53	32	42	98	37	67	0.0	441
4 - 26 - 1972	60	36	48	91	33	62	0.0	434
4 - 27 - 1972	64	40	52	82	26	54	0.0	380
4 - 28 - 1972	62	48	55	98	42	70	0.16	147
4 - 29 - 1972	58	50	54	98	75	86	0.16	156
4 - 30 - 1972	71	50	60	100	52	76	0.0	301
MONTHLY AVER.	59.2	40.2	49.5	96.	52.	74.		256.
						MONTHLY TOTAL	5.79	7684

Fig. 2. Monthly summary of micro-climatic data.

SPRINGER-SANGAMON ENVIRONMENTAL RESEARCH PROGRAM

MICRO-METEOROLOGICAL DATA

WEATHER STATION NO.1 DATE= 4 - 1972

DATE	TEMPERATURE CENTIGRADE MAX	MIN	MEAN	RELATIVE HUMIDITY MAX	MIN	MEAN	PRECIP. MM	RADIATION
4 - 1 - 1972	1.7	-2.8	-0.6	97	65	81	5.84	156
4 - 2 - 1972	4.4	-0.6	1.7	95	49	72	0.25	236
4 - 3 - 1972	6.1	-1.1	2.2	98	74	86	6.35	108
4 - 4 - 1972	6.7	-3.9	1.1	96	39	68	0.0	384
4 - 5 - 1972	16.7	2.2	9.4	88	30	59	0.0	339
4 - 6 - 1972	25.6	6.1	15.6	100	44	72	0.0	290
4 - 7 - 1972	8.9	-5.6	1.7	100	67	84	12.45	89
4 - 8 - 1972	2.8	-6.7	-2.2	87	49	68	0.0	390
4 - 9 - 1972	10.6	-2.2	4.4	96	42	69	0.0	384
4 - 10 - 1972	21.1	12.2	16.7	95	36	65	0.0	276
4 - 11 - 1972	20.0	8.9	14.4	100	33	66	24.89	295
4 - 12 - 1972	19.4	9.4	14.4	100	86	93	0.0	65
4 - 13 - 1972	24.4	8.3	16.1	94	45	69	0.76	371
4 - 14 - 1972	21.1	6.1	13.3	97	61	79	0.51	230
4 - 15 - 1972	18.9	9.4	13.9	100	77	88	0.0	143
4 - 16 - 1972	13.3	3.9	8.3	99	66	82	18.54	158
4 - 17 - 1972	22.2	10.0	16.1	80	36	58	0.0	221
4 - 18 - 1972	24.4	6.7	15.6	98	33	65	0.0	421
4 - 19 - 1972	22.2	13.9	17.8	100	53	76	48.51	208
4 - 20 - 1972	14.4	6.7	10.6	98	77	87	0.0	139
4 - 21 - 1972	13.9	6.7	10.0	100	82	91	20.57	67
4 - 22 - 1972	15.0	6.1	10.6	88	54	71	0.25	382
4 - 23 - 1972	11.7	3.9	7.8	95	51	73	0.0	293
4 - 24 - 1972	10.0	3.3	6.7	98	56	77	0.0	180
4 - 25 - 1972	11.7	0.0	5.6	98	37	67	0.0	441
4 - 26 - 1972	15.6	2.2	8.9	91	33	62	0.0	434
4 - 27 - 1972	17.8	4.4	11.1	82	26	54	0.0	380
4 - 28 - 1972	16.7	8.9	12.8	98	42	70	4.06	147
4 - 29 - 1972	14.4	10.0	12.2	98	75	86	4.06	156
4 - 30 - 1972	21.7	10.0	15.6	100	52	76	0.0	301
MONTHLY AVER.	15.1	4.6	9.7	96.	52.	74.		256.
						MONTHLY TOTAL	147.07	7684

Fig. 3. Metric summary of micro-climatic data.

APRIL 1972 STATION 1
MONTHLY WEATHER DATA-TEMP. (SOLID LINES)-REL. HUMIDITY (LONG DASH)-PRECIPITATION (BARS)-RADIATION (SHORT DASH)
PER CENT RELATIVE HUMIDITY
TEMP. (DEGREES FAHRENHEIT)
RADIATION (CAL./SQ.CM./DAY)
PRECIPITATION (INCHES)
DAY OF THE MONTH

Fig. 4. Graphic summary of micro-climatic data.

Model 763 Digital Incremental Plotter. Portions of the program can be modified to best suit the user's special requirements and needs. The Cal Comp subroutines are locally written for the IBM 360/75 at the University of Illinois and, thus, alteration of the calling statements in the plotting section of the program may be necessary with different systems. The program is designed to list the daily data collected from the weather station, provide monthly sums and averages of the environmental parameters, convert temperature and precipitation values to metric equivalents, and to provide a graphic representation of the original data. For each set of data, whether from different stations or months, an initial input card is required and must precede the daily data cards. Output from the program is illustrated in Figures 2, 3, and 4. The computer program has been reproduced in total in the appendix of this paper.

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APPENDIX

FORTRAN IV COMPUTER PROGRAM

```
C        COMBINED PROGRAM TO LIST AND PLOT WEATHER DATA
C        PROGRAM LISTS DAILY READINGS FOR TEMP.,R.H., PRECIP.& RADIATION
C        FIGURES MONTHLY AVERAGES AND TOTALS
C        CONVERTS TO METRIC UNITS FOR TEMP. & PRECIP.
C        PLOTS MICRO-METEOROLOGIC DATA USING THE CALCOMP PLOTTER
C        FOR EACH STATION'S DATA FOR EACH MONTH AN INTRODUCTORY CARD IS
C NEEDED CONTAINING THE # OF CARDS IN THE SET AND THE HEADING ARRAY
C        FIRST CARD LISTS THE NUMBER OF DAYS IN THE MONTH(COL. 1-2)
C AND A HEADING ARRAY USED IN THE CALCOMP PLOT(COL.3-26)
C        NEXT PUT CARDS FOR MONTH'S WEATHER DATA FOR ONE STATION
C        WEATHER DATA PUNCHED AS BELOW
C        COLUMN  1    = STATION # OR LETTER
C        COLUMN  3- 4 = MONTH
C        COLUMN  6- 7 = DAY
C        COLUMN  9-13 = YEAR
C        COLUMN 15-18 = MAXIMUM TEMPERATURE
C        COLUMN 20-22 = MINIMUM TEMPERATURE
C        COLUMN 24-26 = MEAN    TEMPERATURE
C        COLUMN 31-33 = MAXIMUM RELATIVE HUMIDITY
C        COLUMN 35-37 = MINIMUM RELATIVE HUMIDITY
C        COLUMN 39-41 = MEAN    RELATIVE HUMIDITY
C        COLUMN 46-51 = PRECIPITATION
C        COLUMN 56-59 = RADIATION
C  SAMPLE INITIAL CARD
C        31MARCH   1972   STATION 1
C  SAMPLE DATA CARD
C        0 02 07 1972  +09C +70 +8D    1DD C9D D95    D1.02     DDB2
DDD1          DIMENSION ISTA(31),MONTH(31),IDAY(31),IYEAR(31),ITMAX(31)
             1,XTMAX(31),ITMIN(31),XTMIN(31),ITMEAN(31),XTMEAN(31),PREC(31),IRAD
             1(31),XRAD(31),IHMIN(31),XHMIN(31),IHMAX(31),XHMAX(31),IHMEAN(31),
             1XHMEAN(31),CIMAX(31),CIMIN(31),CIMEAN(31),PRECMM(31),X(31),X1(155)
             1,Y1RN(155),SCX(2),SCY1(2),SCY2(2),SCY3(2),SCY4(2),XMONTH(6),XPREC(
             131)
DDD2          DATA XPREC/31*D.D/,Y1RN/155*D.D/
C        READ # OF DAYS IN MONTH AND HEADING ARRAY
DDD3        1 READ(5,99,END=2DD) N,(XMONTH(I),I=1,6)
DDD4       99 FORMAT(I2,6A4)
C           READ IN WEATHER DATA INTO ONE-DIMENSIONAL ARRAYS
DDD5          READ(5,1DD)(ISTA(I),MONTH(I),IDAY(I),IYEAR(I),ITMAX(I),ITMIN(I),
             1ITMEAN(I),IHMAX(I),IHMIN(I),IHMEAN(I),PREC(I),IRAD(I),I=1,N)
DDD6      1DD FORMAT(A1,2I3,I5,2X,3I4,3X,3I4,4X,F5.2,5X,I4)
C           PRINT OUT PAGE HEADING, ENTER STATION NO., MONTH, & YEAR
DDD7          WRITE(6,1D1) ISTA(1),MONTH(1),IYEAR(1)
DDD8      1D1 FORMAT('1',3DX,'SPRINGER-SANGAMON ENVIRONMENTAL RESEARCH PROGRAM',
            *//' ',42X,'MICRO-METEOROLOGICAL DATA',//' ',9X,'WEATHER STATION NO
            *.',A2,1DX,'DATE=',I2,' -',I5)
C           PRINT OUT WEATHER PARAMETER HEADINGS
DDD9          WRITE(6,1D2)
DD1D      1D2 FORMAT('D',3DX,'TEMPERATURE',15X,'RELATIVE HUMIDITY',11X,'PRECIP.'
            1,1DX,'RADIATICN',/' ',13X,'DATE',9X,'MAX',5X,'MIN',5X,'MEAN',9X,'M
            2AX',5X,'MIN',5X,'MEAN',/)
C           PRINT OUT DAILY WEATHER DATA
DD11          WRITE(6,1D3) (MONTH(I),IDAY(I),IYEAR(I),ITMAX(I),ITMIN(I),ITMEAN(I
             1),IHMAX(I),IHMIN(I),IHMEAN(I),PREC(I),IRAD(I),I=1,N)
DD12      1D3 FORMAT(' ',6X,I3,' -',I3,' -',I5,4X,I4,4X,I4,5X,I4,8X,I4,4X,I4,5X,
            1I4,1DX,F5.2,13X,I4)
C           INITIALIZE INTEGER VARIABLES AND SUM DATA OVER 1 MONTH
DD13          ITMXT=D
DD14          ITMIT=0
DD15          ITMET=D
DD16          ITRHMX=0
DD17          ITRHMI=D
DD18          ITRHME=0
DD19          TPREC=D.D
DD2D          ITRAD=D
DD21          DO 2D I=1,N
DD22          ITMXT=ITMXT+ITMAX(I)
DD23          ITMIT=ITMIT+ITMIN(I)
DD24          ITMET=ITMET+ITMEAN(I)
DD25          ITRHMX=ITRHMX+IHMAX(I)
DD26          ITRHMI=ITRHMI+IHMIN(I)
DD27          ITRHME=ITRHME+IHMEAN(I)
DD28          TPREC=TPREC+PREC(I)
DD29          ITRAD=ITRAD+IRAD(I)
DD3D       2D CONTINUE
```

```
0031              X2=N
0032              AVMXT=ITMXT/X2
0033              AVMIT=ITMIT/X2
0034              AVMET=ITMET/X2
0035              AVRHMX=ITRHMX/X2
0036              AVRHMI=ITRHMI/X2
0037              AVRHME=ITRHME/X2
0038              AVTRAO=ITRAO/X2
                C        PRINT MONTHLY AVERAGES
0039              WRITE(6,104) AVMXT,AVMIT,AVMET,AVRHMX,AVRHMI,AVRHME,AVTRAO
0040            104  FORMAT('0',8X,'MONTHLY AVER.',5X,F4.1,4X,F4.1,5X,F4.1,8X,F4.0,5X,
                   1F3.0,6X,F3.0,27X,F5.0)
                C        PRINT MONTHLY TOTALS FOR INSOLATION AND PRECIPITATION
0041              WRITE(6,105) TPREC,ITRAD
0042            105 FORMAT('0',69X,'MONTHLY TOTAL',3X,F5.2,13X,I4)
                C        CONVERT FARENHEIT TO CENTIGRADE AND INCHES PRECIP. TO MM
0043              DO 30 K=1,N
0044              CIMAX(K)=0.5556*(ITMAX(K)-32)
0045              CIMIN(K)=0.5556*(ITMIN(K)-32)
0046              CIMEAN(K)=0.5556*(ITMEAN(K)-32)
0047              PRECMM(K)=PREC(K)*25.4
0048             30 CONTINUE
                C        PRINT DATA AS ABOVE BUT USE CENTIGRADE TEMPERATURE AND METRIC
                C UNITS FOR PRECIPITATION
0049              WRITE(6,101) ISTA(1),MONTH(1),IYEAR(1)
0050              WRITE(6,109)
0051            109 FORMAT('0',30X,'CENTIGRADE',46X,'MM')
0052              WRITE(6,102)
0053              WRITE(6,106) (MONTH(I),IDAY(I),IYEAR(I),CIMAX(I),CIMIN(I),CIMEAN(I
                  1),IHMAX(I),IHMIN(I),IHMEAN(I),PRECMM(I),IRAD(I),I=1,N)
0054            106 FORMAT(' ',6X,I3,' -',I3,' -',I5,3X,F5.1,3X,F5.1,4X,F5.1,8X,I4,4X,
                   I4,5X,I4,09X,F6.2,13X,I4)
0055              CTMXT=0.0
0056              CTMIT=0.0
0057              CTMET=0.0
0058              TPRECM=0.0
0059              DO 40 M=1,N
0060              CTMXT=CTMXT+CIMAX(M)
0061              CTMIT=CTMIT+CIMIN(M)
0062              CTMET=CTMET+CIMEAN(M)
0063              TPRECM=TPRECM+PRECMM(M)
0064             40 CONTINUE
0065              AVCMXT=CTMXT/X2
0066              AVCMIT=CTMIT/X2
0067              AVCMET=CTMET/X2
0068              WRITE(6,107) AVCMXT,AVCMIT,AVCMET,AVRHMX,AVRHMI,AVRHME,AVTRAO
0069            107 FORMAT('0',8X,'MONTHLY AVER.',4X,F4.1,4X,F4.1,5X,F4.1,09X,F4.0,5X,
                   1F3.0,6X,F3.0,27X,F5.0)
0070              WRITE(6,108) TPRECM,ITRAD
0071            108 FORMAT('0',69X,'MONTHLY TOTAL',2X,F6.2,13X,I4)
                C        THE FOLLOWING STATEMENTS TRANSLATE THE ARRAYS INTO PROPER
                C FORM FOR PLOTTING
0072              DO 23 I=1,N
0073              XTMAX(I)=ITMAX(I)
0074              XTMIN(I)=ITMIN(I)
0075              XTMEAN(I)=ITMEAN(I)
0076              XHMAX(I)=IHMAX(I)
0077              XHMIN(I)=IHMIN(I)
0078              XHMEAN(I)=IHMEAN(I)
0079              XPREC(I)=PREC(I)
0080             23  XRAD(I)=IRAD(I)
                C        SUPPLY SCALING INFORMATION FOR THE AXIS AND LINE DRAWING
                C ROUTINES
0081              SCX(1)=0.0
0082              SCX(2)=2.
0083              SCY1(1)=-20.
0084              SCY1(2)=120./8.
0085              SCY2(1)=0.0
0086              SCY2(2)=100./8.
0087              SCY3(1)=0.0
0088              SCY3(2)=480./8.
0089              SCY4(1)=0.0
0090              SCY4(2)=6./8.
                C        INITIALIZE AN ARRAY TO SERVE AS DAYS OF THE MONTH
0091              DO 92 I=1,N
0092             92 X(I)=I
                C        THE FOLLOWING TRANSLATES THE PRECIPITATION DATA INTO ARRAYS
                C THAT WILL PLOT AS A HISTOGRAM
0093              DO 16 I=1,155
0094             16 X1(I)=I*0.2
0095              DO 18 I=5,155,5
0096              YIRN(I)=XPREC(I/5)
0097              IF(YIRN(I).EQ.0.) GO TO 18
```

```
0098              Y1RN(I-1)=Y1RN(I)
C099              X1(I-1)=X1(I-1)+0.1
0100              X1(I-2)=X1(I-1)
0101              IF(I.EQ.155) GO TO 18
0102              Y1RN(I+1)=Y1RN(I)
0103              X1(I+1)=X1(I+1)-0.1
0104              X1(I+2)=X1(I+1)
0105           18 CONTINUE
                C         THIS CALL REPOSITIONS THE REFERENCE POINT OF THE PLOTTER TO
                C ALLOW AXIS DRAWING
0106              CALL CCP1PL(3.0,1.,-3)
                C         THE FOLLOWING CALLS TO CCP5AX DRAW THE AXES AND LABELS
0107              CALL CCP5AX(0.,0.,'TEMP.(DEGREES FARENHEIT)',24,8.0,90.0,SCY1)
0108              CALL CCP5AX(-1.0,0.0,'PER CENT RELATIVE HUMIDITY',26,8.0,90.0,SCY2
                 1)
0109              CALL CCP5AX(15.5,0.,'RADIATION(CAL./SQ.CM./DAY)',-26,8.0,90.,SCY3)
0110              CALL CCP5AX(16.5,0.,'PRECIPITATION(INCHES)',-21,8.,90.,SCY4)
0111              CALL CCP5AX(0.,0.,'DAY OF THE MONTH',-16,15.5,0.,SCX)
                C         THE CALLS TO CCP6LI PLOT THE ENVIRONMENTAL DATA
0112              CALL CCP6LI(X,XTMAX,N,1,SCX,SCY1)
0113              CALL CCP6LI(X,XTMIN,N,-1,SCX,SCY1)
0114              CALL CCP6LI(X,XTMEAN,N,1,SCX,SCY1)
0115              CALL CCP6LI(X,XHMAX,N,-1,SCX,SCY2,0.15)
0116              CALL CCP6LI(X,XHMIN,N,1,SCX,SCY2,0.15)
0117              CALL CCP6LI(X,XHMEAN,N,-1,SCX,SCY2,0.15)
0118              CALL CCP6LI(X1,Y1RN,155,1,SCX,SCY4)
0119              CALL CCP6LI(X,XRAD,N,-1,SCX,SCY3,-1,1)
0120              CALL CCP6LI(X,XRAD,N,1,SCX,SCY3,0.03)
                C         THE CALLS TO SYMBOL PRINT HEADINGS (OF WHICH ONE IS THE ARRAY
                C XMONTH)
0121              CALL SYMBOL(0.,8.3,0.15,'MONTHLY WEATHER DATA-TEMP.(SOLID LINES)-R
                 1EL. HUMIDITY(LONG DASH)-PRECIPITATION(BARS)-RADIATION(SHORT DASH)'
                 1,0.,106)
0122              CALL SYMBOL(0.,8.5,0.15,XMONTH,0.,24)
                C         THE FOLLOWING WRITE STATEMENT ENSURES THAT NO DIAGNOSTICS
                C OR OTHER NON RELATED PRINTING WILL OCCUR ON THE DESIRED PRINTOUT
0124           200 WRITE(6,847)
0125           847 FORMAT('1','END OF DATA')
0126              STOP
0127              END
```

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THE 1972-1973 GOSHAWK INVASION IN ILLINOIS

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Abstract.--The distribution and magnitude of the 1972-1973 goshawk invasion in Illinois is reported. The greatest numbers of goshawks were recorded from northern Illinois, but some individuals ranged as far south as Pope and Union counties. Information is provided on the age composition of the invading individuals; 85% of the aged birds were considered to be in subadult or adult plumages. A brief review of a possible cause of periodic invasions is included.

During the fall and winter of 1972-1973, a historically unprecedented number of goshawks *(Accipiter gentilis)* ingressed into Illinois. Previous southern irruptions occurred in Illinois during the years 1870-1871 (Nelson, 1876), 1896-1897 (Dickensen, 1897), 1907-1908 (Deane, 1907), and 1916-1917 (Eifrig, 1917; Musselman, 1921) but in much smaller numbers than the 1972-1973 invasion.

Between 1921 and 1972, Christmas Bird Censuses of the Illinois Audubon Society reported goshawks occurring sporadically in the following northern counties: Bureau, Carroll, Cook, DuPage, Lake, Lee, McHenry, McLean, Mercer, Peoria, and Rock Island. In the 1949 *Audubon Field Notes (=American Birds)*, five goshawks were reported from Havana, but no details were submitted with the report. Mueller and Berger (1967) listed two recovered banded birds from Cook and Adams counties (originally banded at Cedar Grove Ornithological Station, Wisconsin which are the only band recoveries on record for Illinois), and Smith and Parmalee (1955) cited a record for Madison County that until now was the most southwestern Illinois record. A review of the records of the Fish and Wildlife Service's Bird Banding Laboratory from 1954 to 1971 revealed that of 1,050 goshawks banded in the United States during this period, none was trapped in Illinois.

This paper delineates the distribution of the 1972-1973 invading goshawks in Illinois and provides information on the magnitude of the invasion and on the age composition of the invading individuals.

To determine the abundance and distribution of goshawks in Illinois, data sheets were sent to museums and universities in Illinois and adjoining counties requesting information on specimens received between September 1972 and April 1973. Included on the data sheets were collecting information as outlined by Van Tyne (1952) and supplementary space for comments on behavior, unusual circumstances, and other pertinent remarks.

Additional data sheets, or letters requesting information on observations for trapped goshawks, were sent throughout the state to individuals known to have previously contributed information on other Illinois bird species. The data accumulated were considered reliable, although a few

records from different observers may represent reports of the same bird.

Museum specimens are deposited in the following institutions (abbreviations used in text): Davenport Museum (DP), Greenville College (GC), Illinois Natural History Survey (INHS) and Illinois State Museum (ISM).

DISTRIBUTION AND MAGNITUDE OF THE INVASION

A total of 243 goshawks was reported, including nine museum specimens (DP 1, GC 1, INHS 6, ISM 1), 68 trapped birds, and 166 observations. The earliest and latest dates recorded were 30 September 1972 and 8 April 1973. In contrast, Ford, et al. (1934) gave 28 October and 3 March as the earliest and latest dates for the Chicago region.

Goshawks were reported in greatest numbers in the northern one-fourth of the state but ranged as far south as Pope and Union counties (Fig. 1). Although the AOU Checklist (5th edition) states that the wintering range of the goshawk extends as far south in the central states as Tennessee, no records from southern Illinois have previously been known.

An examination of Illinois topographic maps discloses that in 1972-1973 goshawks were found predominantly in heavily wooded areas and forests marginal to open land. In forested areas such as the Max McGraw Wildlife Foundation, Sand Ridge State Forest, and state game farms, goshawks were seen regularly throughout the winter.

AGE COMPOSITION

The age composition of the invading goshawks was determined by summarizing the data obtained from the trapped birds and specimens. Seventy-five goshawks were aged, 66 by trappers at their stations (Fig. 1), and nine through examination of museum specimens. The majority of adults trapped had two generations of feathers in their plumage, permitting their placement into three age classes (based on differences in color and pattern). Eleven were juveniles (less than one year old), 25 were subadults (birds exhibiting first adult plumage, slightly more than one year old) and 39 were adults (birds exhibiting their second or subsequent adult plumage, two or more years old). These age classes follow those outlined by Mueller and Berger (1967). Eighty-five percent of the goshawks represented the subadult and adult plumages.

The proposal that goshawk populations increase as prey populations increase, resulting in an overabundance of goshawks when the prey species decline, has been suggested by Spiers (1939), Keith (1960) and Mueller and Berger (1967). With a decline in prey populations and an increase in agonistic encounters among a given population of goshawks, the production of young decreases (Mueller and Berger 1967). The invasion in 1962-1963 reported by Mueller and Berger contained few juveniles and first-year adults, thus supporting the above hypothesis.

Of the 75 goshawks aged in the 1972-1973 invasion, only 15% were juveniles, reflecting a low reproductive success in 1972 and adding further support to the aforementioned hypothesis.

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Figure 1. Distribution of *A. gentilis*. Large dots indicate localities represented by museum-acquired specimens; small dots indicate localities represented by sight records; triangles indicate trapping station localities. The number of localities does not accurately reflect the total number of birds reported.

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ESKERS OF NORTHERN ILLINOIS

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ABSTRACT

At least twenty-seven eskers and esker groupings occur in northern Illinois. These range in age from early Illinoian to late Wisconsinan. A few are large and conspicuous, but the majority are small. Many of the larger eskers have been extensively modified as a result of quarrying operations.

INTRODUCTION

Among the most interesting of glacial landforms are the eskers. These elevated ridges of sand and gravel, often sinuous in plan view, offer a striking witness to the glacial heritage of a region. Although not as abundant as in some of the glaciated regions of the world, eskers are known in a number of localities within northern Illinois. Some of these eskers have been previously described (Table 2), but the total has never been cataloged.

ORIGIN AND CHARACTERISTICS OF ESKERS

The origin and character of eskers is treated in most works on glacial geology and geomorphology. Some of the more extensive and recent treatments are given by Embleton and King (1968), Fairbridge (1968), and Flint (1971). Some of the salient characteristics of eskers are discussed, particularly as these apply to the eskers of northern Illinois.

Eskers form as the result of deposition of stream-laid glacial deposits - usually sand and gravel - in channels confined by glacial ice. The depositional agent is the meltwater produced as a glacier wastes. The sand and gravel is derived from the load of solid detritus transported by the glacier. The flowing water sorts the naturally heterogeneous load of the glacier, sifting out and removing all but the larger particles. The latter accumulate in the channel and remain as the esker after complete wastage of the glacier.

Eskers channels may be of three distinct types, subglacial, intraglacial, or superglacial. Subglacial channels are probably the most common. These consist of tunnels located at the base of a glacier. Water derived from melting of a glacier works its way down into the glacier through crevasses and other openings in the ice. When the water reaches the base of the glacier its further downward movement is inhibited, and it thereafter tends to move laterally. During this lateral movement tunnels may be opened, which - if later filled with stratified drift - become eskers. Since the flowing water always tends to seek the lowest level, ice tunnels and hence eskers most commonly occur in low areas such as valleys or topographic sags on the subglacial surface. This characteristic is pronounced in several of the eskers in northern

Illinois, notably the Leaf River Esker, Pecatonica Esker System, Wyanet Eskers, Winfield Esker, and Tiedtville Esker.

Intraglacial and superglacial channels differ from subglacial channels in that they are located within and on top of a glacier, respectively. Formation in intraglacial or superglacial channels is most often suggested for eskers which increase in elevation in the downstream direction, or which trend across topographic highs. It is believed that these characteristics are likely to develop only if the drift of the eskers had been let down onto the subglacial surface as the reslut of melting of the intervening ice. However, eskers with the same characteristics could also form in a subglacial channel if the hydrostatic head provided by the water entering the tunnel was sufficient to force the water up and over gentle slopes. Eskers which have been let down through any great elevation should bear evidence of this history in the presence of an unusually large amount of contorted and faulted bedding.

Water flow on or within a glacier is always directed in a general way toward the glacier margin. Hence eskers tend to be aligned with their long axis perpendicular to the ice margin. If deposition in the channel extends completely to the glacier margin, a delta may form where the emerging water flow spreads out and thus loses some of its transporting power. A delta of this type appears to occur on the Kaneville Esker.

Most workers consider that eskers form only under stagnant glaciers, else the moving ice would close the tunnel before deposition could fill it or the deposits would be themselves moved and their form destroyed. If this conclusion is correct, it implies that eskers are only formed late in the history of a particular glacier. Since eskers are less abundant in northern Illinois than in many other glacial terrains, it further implies that the glaciers in Illinois were more active than was the norm.

The sediments of which an esker is composed are similar in lithology to the till and bedrock of the local region. In northern Illinois where dolomite forms the predominant bedrock type, dolomite is the most common rock constituent, at least among the large clasts. Lesser amounts of rock derived from more distal regions are also evident, particularly igneous and metamorphic rocks derived from Canada and the northern Great Lakes region.

Cross-bedding is the most common sedimentary structure seen in the strata of eskers. The cross-bedding is useful for determining the direction of flow of the water which formed the esker. The cross-beds dip in the downstream direction. Other evidences which also assist in determing the direction of flow include cobble imbrication, changes in average grain size of the clasts, morphologic features such as the presence of a delta, and the inferred position of the glacier margin.

Because most eskers are formed within the confines of ice walls, they tend to collapse somewhat when the glacial ice melts. The collapse is manifest by the presence of small tensional faults and slumps located at the sides of eskerine ridges.

Since eskers are developed in channels, the form they possess depends upon the form of the channel as well as the degree to which the channel becomes filled.

Ice tunnels commonly consist of alternating broad expanses, or "rooms", and narrower passageways, similar in character to limestone caverns. When filled this type of tunnel produces a series of knolls marking the position of the rooms and a series of narrower segments marking the position of the passageways. In the extreme case no deposition may occur in the passageways due to the greater velocity of water flow through the narrows. The result is a train of kamic knolls representing just the rooms. Several such examples occur in northern Illinois.

Most eskers display some curvature when seen in plan view. The curvature mirrors the curvature of the channel. Some of the best developed eskers have markedly sinuous patterns much like that seen in meandering streams.

If an ice-channel becomes choked with debris--as it must to produce an esker--an increase in the water flow often can not be accomodated by the restricted channel. The result is that new channels are opened. They may diverg from the initial channel, or run parallel to it. When the new channel becomes filled, a companion esker is left. The process may repeat to the point where very complex eskerine tracts are produced. A particularly complex type of tract occurs where the main ice tunnels diverge into a number of distributary tunnels, such as is seen in the Stillman Valley Eskerine Tract (Figure 2).

If ice blocks become buried in sand and gravel during the formation of an esker deposit, their later melting leaves kettles within the esker. These depressions may then completely or partially fill with foreign material, such as loess, coluvium, or peat.

Dimensions of eskers run a broad gamut. Eskers several tens of miles long are known, although those of lesser length are most common. The longest esker in northern Illinois is the 10-mile long Leaf River Esker. Breadths of eskers range from a matter of feet to a half-mile or more. The wider eskers are generally compound. Relief on eskers may range anywhere upwards of a few feet. Eskers of low relief may be difficult to recognize and their presence revealed only by detailed mapping. Relief is the quality most susceptable to modification once an esker becomes exposed to erosion. Hence, older eskers tend to have less conspicuous relief than newer eskers. The sand and gravel of eskers may extend below the level of the till or other materials which surround the esker. In this case the sand and gravel is thicker than the esker is high.

Eskers commonly occur in association with other glacial landforms. The most abundant associates are kames. In fact, kames may be considered to be part of a continuous spectrum of water-laid glacial landforms which includes the eskers. Eskers also commonly occur on maraines, particularly in the low sags of moraines.

In the late stages of formation, some ice tunnels may have their roofs collapse, leaving the tunnel open to the air. Features formed by deposition in such open channels are termed crevasse fillings rather than eskers. However, the deposits and the morphology of eskers and crevasse fillings are so similar that their distinction is somewhat artificial. It is possible that some of the features herein described as eskers formed in part or in total as crevasse fillings.

AGE OF ESKERS

Unless an esker contains materials which can be dated by the radiocarbon method, the only way in which the origin of an esker can be placed in time is to assume that it formed contemporaneously, or nearly so, with the tills which surround it (Table 1). Although this procedure is generally reliable, in some instances it can lead to error. A few examples are known where an esker is older than the surface till surrounding it. This can occur when a younger glacier overrides an esker, but does not destroy it. Other instances may occur where, through non-deposition or erosion of till next to an esker, the surface till is older than the esker. The procedure also presupposes that the age of the till can be determined. In the following discussion and in Table 2 age assignments are based on the age of the adjacent tills, unless otherise noted.

TIME UNITS			YEARS BEFORE
AGE	SUBAGE	TILL UNITS	PRESENT*
W		.....	13,500
I		Wadsworth-Haeger Tills	
S		Yorkville Till	
C	WOODFORDIAN	Malden Till	
O		Tiskilwa Till	
N		Esmond Till	
S		.....	20,000
I			
N	ALTONIAN	Argyle Till	
A			
N	.....		75,000
	.....		125,000
I			
L	JUBILEEAN		
L			
I			
N	MONICAN	Ogle Till	
O			
I			
A	LIMAN	Kellerville Till	
N	.....		(?)

TABLE 1. Relationship of time units to till units. Only terms used in text are presented. For complete discussion, see Willman and Frye (1970). (* Dates in radiocarbon years and/or estimates).

NO.	NAME	MAX. HGT. (Ft)	LTH. (Mi)	LOCATION				TOPO. QUAD	REFERENCES	
				COUNTY	SECTIONS	TWN	RANGE		DISCUSSION	MAP
					ILLINOIAN ESKERS					
1	Garden Plain	20	4	Whiteside	20-24	21N	3E	Clinton	27, 35, 38	35
2	Hazelhurst	100	1½	Carroll-Ogle	21-22, 27	23N	7E	Sterling	35	4, 35
3	Leaf River (Adeline)	100	10	Ogle	19-24 19, 28-30	25N 25N	8E 9E	Forreston-Oregon	9, 16, 22 33, 35, 39	4, 35, 40
					ALTONIAN ESKERS					
4	Pectonica	20	1/3**	Stephenson	34-36	27N	8E	Freeport	11, 22, 31, 35	11, 35
5	Irene	80	3½	Boone-DeKalb	19-20, 29-32 5	43N 42N	3E 3E	Kirkland	1, 35	1, 23, 40
					WOODFORDIAN ESKERS (ESMOND TILL)					
6	Stillman Valley	60	2**	Ogle	5, 7-8, 18 35-36	42N 25N	1E 11E	Kings	6, 28, 35	6, 40
7	Holcomb	15	1½	Ogle	3-4	41N	1E	Kings	6	6
8	Grand Detour	30	5½	Lee	14-15 23, 25-26 31 5-6	22N 22N 22N 22N	9E 9E 10E 10E	Dixon	25, 29, 32	32

TABLE 2. Eskers of northern Illinois. Esker numbers are keyed to text discussion and location map (Figure 1). Reference numbers are keyed to LITERATURE CITED. Esker names with asterisks are new names. Double asterisks in the length column indicate the length of the longest ridge in a cluster.

WOODFORDIAN ESKERS (TISKILWA TILL)

9	Wyanet*	70	2½**	Bureau	24-25	16N	7E	Buda	30, 37	37
10	Cortland*	60	5½	DeKalb-Kane	9-10, 15-16	40N	5E	Sycamore	1	1, 21, 40
					22-24	40N	5E			
					19	40N	6E			
11	Kaneland School*	50	8½	Kane-DeKalb	12	39N	5E	Sycamore-Geneva		1, 5, 12, 20
					1-8	39N	6E			
					6	39N	7E			
					31-32	40N	7E			

WOODFORDIAN ESKERS (MALDEN TILL)

12	Little Rock	15	1	DeKalb	5-6	38N	5E	Sycamore	35	1, 4
13	Kaneville	70	7	Kane	25	39N	6E	Geneva	20, 26, 34	4, 5, 12
					30-31	39N	7E		35, 36	20, 35, 36
					5-6, 8-10, 15	38N	7E			40, 42
14	Covel Creek	20	7	LaSalle	4-6	32N	4E	Ottawa	35, 44	40, 44
					1-5	32N	3E			

WOODFORDIAN ESKERS (YORKVILLE TILL)

15	Brookfield*	10	1/5	LaSalle	5,8	32N	5E	Marseilles	44	44
16	Wheatland	15	1/2	Will	19	37N	9E	Normantown	15	15, 42
17	Naperville	15	1	DuPage	26-27	38N	9E	Normantown	15	12, 15, 42
18	Warrenville*	20	1	DuPage	3,10	38N	9E	Naperville	41	12, 41

TABLE 2 (con't).

WOODFORDIAN ESKERS (WADSWORTH AND HAEGER TILLS)

19	Orland Park*	25	1**	Cook	8-9, 18	36N	12E	Tinley Park-Mokena		7, 12, 42
20	Visitation	20	3/4	Cook	19-20	37N	12E	Sag Bridge	8	7, 12, 42
21	Hickory Hills*	25	2/3	Cook	2	37N	12E	Palos Park		7, 42
22	Tiedtville	25	½**	Cook	31 6	38N 37N	12E 12E	Sag Bridge	8	7, 12, 42
23	Oak Brook Terrace*	20	½**	DuPage	23, 27	39N	11E	Hinsdale	8	7, 42
24	Itasca*	30	1½	DuPage	12 7-8	40N 40N	10E 11E	Lombard		12, 42
25	Winfield*	30	½	DuPage	15	39N	9E	Naperville	41	41
26	Halfday*	15	½	Lake	15	43N	11E	Wheeling	8	7, 42
27	Island Lake*	50	1½**	Lake	13-16, 21	44N	9E	Wuaconda		12

TABLE 2 (con't).

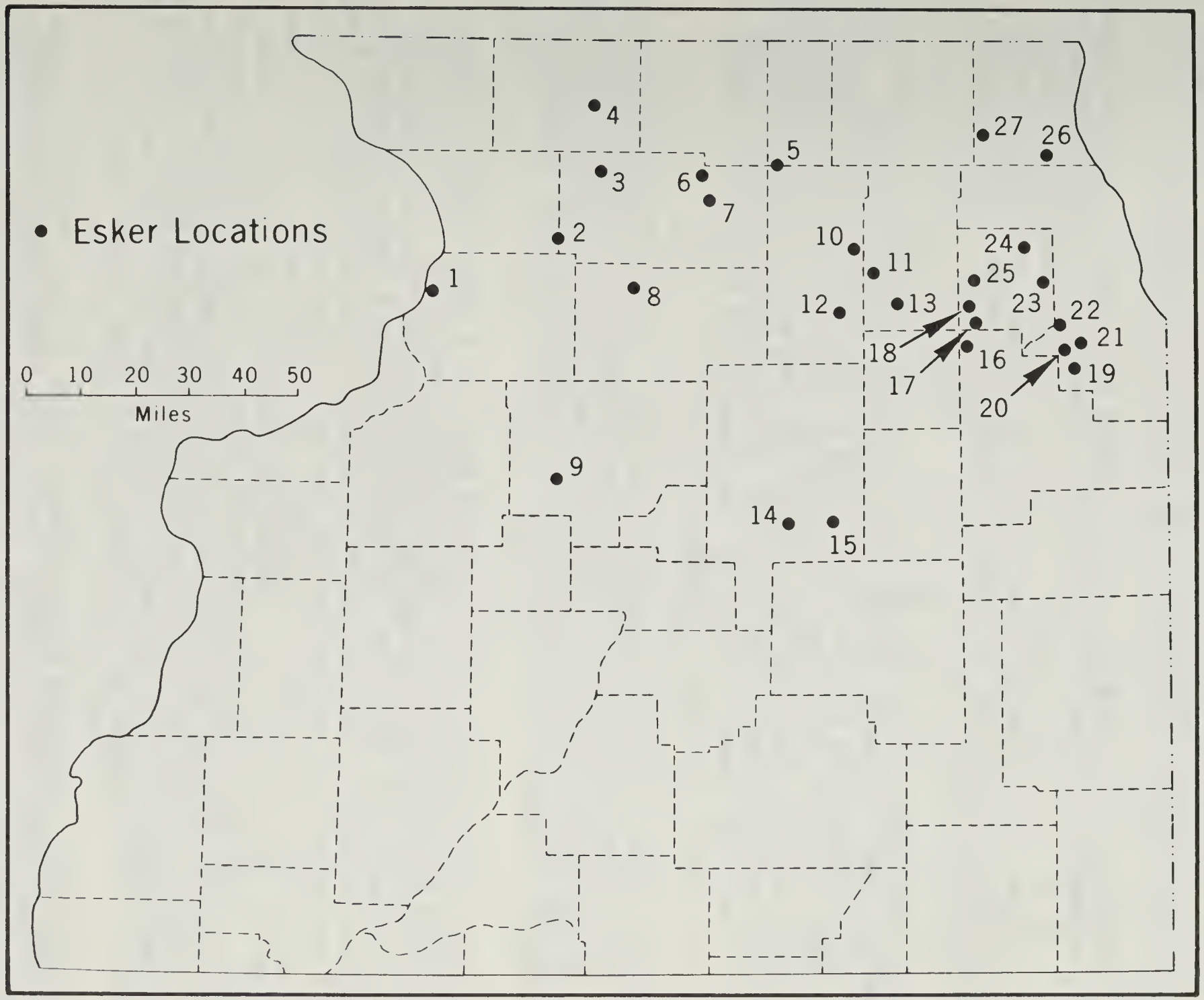

Figure 1. Location of eskers in northern Illinois. Numbers are keyed to text descriptions and to Table 2.

ILLINOIAN ESKERS

Three eskers of probable Illinoian age are known in northern Illinois (Table 2). Each occurs in the northwestern part of the state (Figure 1) where Illinoian drift occurs at the surface (Frye et al, 1969). In spite of their relative antiquity, two of these eskers, the Hazelhurst and Leaf River Eskers, are among the most prominant of the eskers of Illinois.

A linear exposure of sand and gravel located at Elmwood in western Peoria County may represent a fourth Illinoian esker. Thornburn's (1963) map shows the feature as an ice-contact deposit. However, Anderson and Hunter (1965) described it simply as Illinoian outwash. If the feature is indeed an esker, it has suffered extensive erosional modification since it no longer possesses a well-defined ridge-form.

Garden Plain Esker (#1) The Garden Plain Esker is a weakly express, eastward trending ridge located in Garden Plain Township, Whiteside County. Relief on the ridge averages only 5 to 10 feet. Some of the low relief has resulted from partially burial of the ridge by Wisconsinan loess. Leverett (1899) was able to trace the ridge for 2½ miles. Since then the esker has been traced in the subsurface an additional 1½ miles to the east. Quarries located at the west end of the ridge reveal the typical sand and gravel composition of an esker. Cross-bedding indicates a westward direction of flow.

Leverett (1899) initially suggested a possible Illinoian age for the esker. Schaffer (1956) reassigned the esker to an early Woodfordian (Tazewell) age. The most recent mapping has tended to confirm Leverett's assignment: the till adjacent to the esker is the Kellerville Till of Early Illinoian (Liman) age (Willman and Frye, 1970).

Hazelhurst Esker (#2) The Hazelhurst Esker is a short but well-defined ridge located at Hazelhurst on the Carroll-Ogle county line. The main ridge of the esker is traceable without break for about 1½ miles. Several prominant gravel knolls located to the south and east of the main ridge are probably continuations of the esker. If the latter are added, the total length of the esker is about three miles. At the western end the main ridge splays out into a number of digitated fingers, in a pattern similar to that displayed in the Stillman Valley Eskerine Tract (Figure 2). The maximum height of the esker is about 100 feet, with much of the ridge rising 60 to 75 feet. Leverett (1899) reported that a well made on the slope of the esker a short distance west of Hazelhurst penetrated a 100-foot section of sand and gravel before entering bedrock. At other places in the immediate vicinity bedrock occurs either at or very near the surface. Shaffer (1956) described a section of the strata in the esker.

Shaffer (1956) considered the Hazelhurst Esker to have formed in Farmdale (earliest Wisconsinan) time. However, Frye et al (1969) concluded that the surface till in the vicinity of the esker is the Ogle Till, which is assigned to the Monican Subage of Illinoian time (Willman and Frye, 1970).

Leaf River (Adeline) Esker (#3) The Leaf River, or Adeline, Esker was firs noted by Shaw (1873) who mistakenly identified it as a moraine. It was later dis cussed and correctly identified as an esker by Chamberlain (1882), Hershey (1897) and Leverett (1899).

The Leaf River Esker is located in the valley of Leaf River in northwestern Ogle County. It has the distinction of being the longest and one of best-developed eskers in Illinois. Although it has not been mapped in detail, it is at least ten miles in length, extending from a point one mile east of Adeline westward to at least three miles northwest of Forreston. Most of the esker lies immediately north of Leaf River where it rises sharply above the river flats. Near its eastern end, two miles west of Adeline, Leaf River cuts through the esker, placing the ridge south of the river. A second notable gap occurs immediately north of Forreston where a small stream tributary to Leaf River crosses through the esker.

The Leaf River Esker has the uneven, undulating crest line typical of an esker. The highest points slightly exceed 100 feet above the plain bordering Leaf River, but their elevation is no greater than that of the uplands on either side of Leaf River Valley. The lowest points are scarcely 20 feet in height. The esker consists usually of a single ridge, ranging in breadth from 100 feet or less to about 1000 feet. However, at its eastern end the single ridge diverges into a series of poorly defined, nearly parallel ridges and hillocks which cover a breadth of approximately one-half mile and almost fill the valley. At the western end of the ridge there is no delta, or fan-shaped gravel deposit, such as often occurs at the terminus of an esker.

There are a number of quarries in the Leaf River Esker, most of which occur in the western third of the ridge where they have greatly altered the ridge-form character of the esker. The quarries reveal the typical sand and gravel composition of eskers. Shaffer (1956) describes the section in two of these quarries. Cross-bedding in the sands indicates that the flow of water responsible for forming the esker was directed toward the west, or reverse from the direction of flow of modern Leaf River.

Shaffer (1956) assigned the origin of the esker to Farmdale (earliest Wisconsinan) time. However, like the Hazelhurst Esker, the Leaf River Esker has most recently been assigned an Illinoian age on the basis of the occurrence of Illinoian Ogle Till in the surrounding region (Frye et al, 1969).

ALTONIAN ESKERS

Altonian time produced only one prominant esker in northern Illinois, the Irene Esker. However, a number of short ridges collectively referred to as the Pecatonica Esker System probably also represent Altonian eskers. Two Parallel trains of aligned kames mapped by Hunter and Kempton (1967) in southern Boone County may represent still other indistinct eskers.

Pecatonica Esker System (#4) Doyle (1965) interpreted four short ridges located in the Pecatonica River Valley two miles east of Freeport as either eskers or crevasse fillings. The ridges are 10 to 20 feet high, up to a few hundred feet across, and up to one-third mile in length. Three of the ridges lie parallel to one another on a spur of land which extends into the Pecatonica River Valley from the south. The fourth lies to the east on a spur which enters the valley from the north. The local surface till is the Argyle Till of Altonian age (Frye et al, 1969).

The four ridges identified by Doyle are a portion of a much larger belt of eskers which Hershey (1897) thought occurred in the region. Hershey believed that the Pecatonica Esker System extended for a length of nearly 20 miles along the valley of Pecatonica River from eastern Stephenson County westward to beyond Freeport. Hershey also identified two other esker belts in Stephenson County. There were the 20 mile long Cedarville belt, which passed near the community of that name, and the shorter Orangeville belt. Boyle's mapping has cast doubt on the interpretation of these belts as eskerine in orgin. Many of Hershey's localities appear to be either isolated kames or till deposits incorrectly identified as stratified sand and gravel.

Irene Esker (#5) The Irene Esker is a prominant esker located in southwestern Boone and northwestern DeKalb Counties. Its identification is based on the mapping work of Anderson (1964) and Hunter and Kempton (1967) which revealed the sand and gravel composition of the ridge. The main ridge of the esker has a length of two miles. Three isolated gravel knolls located to the north of the of the main ridge produce a cummulative length of about 3½ miles. A fourth knoll located to the west of the main ridge appears to be a spur leading away from the esker proper. Relief is sharp, with the highest portions of the esker rising 80 feet above the surroundings. At its widest the esker spans one-half mile. The surface till of the region is the Argyle Till of Altonian age (Frye et al, 1969).

WOODFORDIAN ESKERS (ESMOND TILL)

Two single-ridge eskers, the Holcomb and Grand Detour Eskers, plus the complex eskerine terrain located at Stillman Valley in Ogle County, have been described from areas where the Esmond Till (earliest Woodfordian) is the surface till (Frye et al, 1969). Although earliest Woodfordian is therefore the most likely time of origin of these eskers, one or more of them may have formed at earlier times. The Esmond Till is thin and has an irregular, patchy surface distribution. It is thus difficult to determine the precise area covered by the Esmond glacier.

Stillman Valley Eskerine Tract (#6) The Stillman Valley Eskerine Tract is notable for its great topographic complexity. The tract consists of three major sub-parallel ridge groups (Figure 2). The central group is dominated by a single long ridge which rises up to 50 feet above the immediate surroundings. The crest of the central ridge is undulatory and varies in altitude with variations in the elevation of the subjacent land. Of the two flanking ridge groups, the western is the most striking. It digitates into not less than thirteen short spurs, which diverge through 180 degrees (Figure 2). From the south these spurs appear as steep knolls rising above the floor of Stillman Creek Valley. Several of the spurs have knoll-like summits, but it is clear that all are connected as one group of radiating ridges. The eastern ridge group is patterned like the western, but the branching finger-like termini are fewer, longer, and generally not so conspicuous.

All of the ridges consist of sand and gravel, in contrast to the till or bedrock which underlies the adjacent landscape. Several quarries reveal that the depth of sand and gravel is equal to the height of the knolls. The subjacent material is usually till, but at least at one locality gravel rests directly on dolomite bedrock.

The branching distributary network of channels represented by the individual ridges of the Stillman Valley Eskerine Tract is strongly suggestive of the type of distrubutary systems seen on modern alluvial fans and deltas, environments in which large changes in stream competancy and capacity are common. Similar stream changes were probably responsible for forming the Stillman Valley Eskers. A likely hypothesis is that at the start only a single ice tunnel existed. Debris gradually began to fill this tunnel, perhaps stimulated by initial deposition near the mouth of the tunnel where the stream spread out and thus has its velocity checked. This accumulation would have lessened the average slope in the tunnel and promoted further deposition within the tunnel. Eventually deposition must have choked the tunnel, forcing the flow of water to diverge, perhaps into already weakened crevasse lines, to open new tunnels. With repeated choking and establishment of new tunnels, the branching network of the eskerine tract would have resulted.

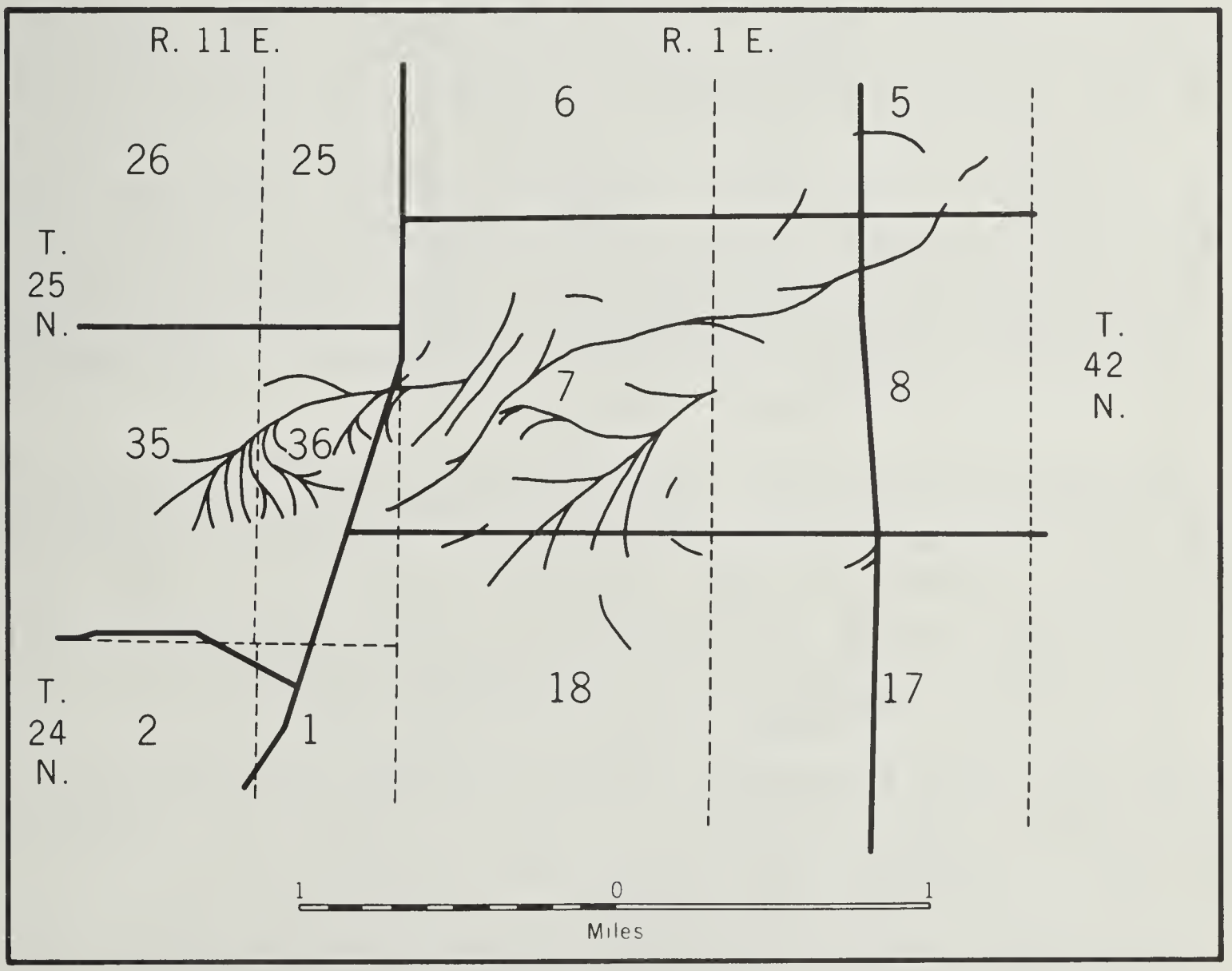

Figure 2. Branching pattern of esker ridges in the Stillman Valley Eskerine Tract (after Bretz, 1923).

Holcomb Esker (#7) The Holcomb Esker, described by Bretz (1923) as a kame tract, is a topographically inconspicuous 1 1/2 mile long ridge located near Holcomb in Ogle County. Although identification of the Holcomb feature as an esker is problematical, its ridge-form and gravelly character tend to support an eskerine origin.

Grand Detour Esker (#8) The Grand Detour Esker, as mapped by Knappen (1926), extends for 5 1/2 miles across Dixon and Nachusa Townships in Lee County. In only a few places is the esker topographically distinct and its extent has been based mainly on the occurrence of sand and gravel on stream divides. These deposits, which have been locally quarried, do suggest an eskerine origin, however, in their linear distribution, in their coarseness, and in their bedding characteristics.

An interesting aspect of the Grand Detour Esker is the role that it may have played in determining the local course of the Rock River. In the vicinity of the esker the Rock River has a large horseshoe-shaped bend, the Grand Detour, which is the source of the name of both the community of Grand Detour and the esker. The presence of the bend adds about five miles to the length of the Rock River. Extending across the neck of the horseshoe bend is a partially drift-filled, half-mile wide and 100 foot deep bedrock valley. The Grand Detour lies athwart the northeast end of this valley. Knappen (1926) suggested that this valley was the course of the Rock River before the Grand Detour Esker was formed. According to Knappen, when the ice under which the esker was formed left the area, the presence of the esker across the old valley blocked the Rock River and caused it to divert into the Grand Detour course. Although this idea is attractive, it may be that factors other than the presence of the esker are actually responsible for the Grand Detour. It is possible that the ice itself, rather than the esker it left, caused the diversion. A second possibility is that the Grand Detour is controlled by zones of weakness in the bedrock. The bedrock is locally deformed as part of the extensive LaSalle Anticlinal belt (Knappen, 1926).

The Grand Detour Esker was considered by Knappen (1926) to be Illinoian in age. However, a roadcut described by Frye et al, (1969, p. 34-35) in the flank of the esker as mapped by Knappen revealed both Esmond Till and Arygle (Altonian) Till beneath the esker. The esker is therefore no older than the Esmond Till.

WOODFORDIAN ESKERS (TISKILWA TILL)

An esker complex, the Wyanet Eskers, and a single-ridge esker, the Cortland Esker, comprise the known eskers on the Tiskilwa Till surface. A third esker, the Kaneland School Esker, which is located on the younger Malden Till surface, was probably also formed by the Tiskilwa glacier.

Wyanet Eskers (#9) The Wyanet Eskers consist of a complex of ridges located two miles southwest of Wyanet in Bureau County. MacClintock and William (1959) mapped seven separate ridges, the longest of which is 2 1/2 miles in length. Relief reaches a maximum of 70 feet. The ridges are arrayed along two parallel trends which evidently represent two separate tunnel systems.

The Wyanet Eskers illustrate well the controll exerted on the position of eskers by subglacial topography. The eskers are located on the Bloomington Morainic System at a position where the system crosses the broad Princeton Bedrock Valley. The latter marks the pre-Woodfordian course of the Mississippi River (e.g., Willman and Fry, 1970). The moraines of the Bloomington System are draped across the valley such that their elevations are as much as 200 feet lower than they are immediately outside the valley. The Wyanet Eskers are clustered in this moranic sag. Presumably water from beneath the Bloomington ice flowed out through the lowest available spot, the sag. In the process ice tunnels -- and eventually eskers -- were formed. Significantly, the till in the sag is also atypical of the Tiskilwa Till: it is much more gravelly than is the norm, indicative of a great amount of water movement through the sag. Associated with the gravelly till are a number of kames and kettles, in addition to the eskers.

Cortland Esker (#10) Anderson (1964) mapped a 5 1/2 mile long esker located two miles northeast of Cortland in east-central DeKalb County and adjacent Kane County. This esker is herein named the Cortland Esker for its proximity to the community of that name.

The Cortland Esker consists of two segments. The broad, arcuate northwest section is 2 1/2 miles long and rises to heights of 60 feet above the adjacent till surface. The narrower and straight 2 mile long southeast segment is bordered by valley train outwash, from which it rises a maximum of 30 feet. The valley train deposits, which are younger than the esker, have partially buried and subdued the relief of this segment. The two segments are separated by a one-half mile wide gap evidently cut through the esker by outwash plain streams issuing from the south (Anderson, 1964, plate 1). Although the flow responsible for forming the esker was probably directed toward the northwest, the northwest segment of the esker is higher than the southeast segment by an average of 35 feet.

The till surrounding the northwest segment of the Cortland Esker is the Tiskilwa Till of Woodfordian age (Gross, 1970). The outwash which partially covers the southeast segment was deposited from the Malden glacier, also of Woodfordian age.

Kaneland School Esker (#11) The Kaneland School Esker is comprised of a linear train of kamic hills which extends from three miles southwest of Maple Park in east-central DeKalb County to north of Elburn in west-central Kane County. The kamic train has been mapped by Anderson (1964) in DeKalb County and by Gross (1969) and Block (1960) in Kane County. The name of the esker is derived from Kaneland High School, located one-half mile south of its middle portion.

The Kaneland School kamic train is probably an esker, although it has not been previously identified as such. Its eskerine origin if favored on the basis of both the linear alignment of the individual knolls and the bedding characteristics of the sand and gravel comprising the knolls. The latter consists of low-angle strata with gentle cross-bedding, quite atypical of normal kame deposits.

One of the apparent difficulties with interpreting the Kaneland School kamic train as an esker is that the trend of the train parallels the local moraines (Willman and Frye, 1970). The moraines mark the outer boundary of the Malden Till, which is the local surface till (Gross, 1969 and 1970). This relationship suggests a situation opposite to that normally witnessed with eskers, which tend to be aligned perpendicular to moraines. This difficulty has been resolved in a former exposure located immediately north of Kaneland School. The exposure showed a layer of Malden Till superimposed on the sand and gravel of the esker. The sand and gravel itself was faulted, suggesting that it had been shoved. Evidently the Kaneland School Esker was formed previous to the development of the Malden glacier, probably during the time of the Tiskilwa glacier. The Malden glacier later partially covered, but did not completely destroy the esker.

The individual knolls of the Kaneland School Esker may have formed in "rooms" separated by narrower passages of the overall ice tunnel. Some of the knoll development, however, may have resulted from differential scour as the Malden glacier passed over the esker. The latter hypothesis is favored by the observation that strata in the knolls appear to be erosionally truncated at the knoll margins.

WOODFORDIAN ESKERS (MALDEN TILL)

The Malden Till region contains three known eskers. Two of these, the Little Rock Creek and Covel Creek Eskers, are fairly indistinct. The third, however, is one of the largest and best developed of the eskers in northern Illinois. This is the famous Kaneville Esker.

Portions of the Malden Till region, particularly within eastern DeKalb, central Kane, and southern McHenry Counties, contains an unusually high density of kames (e.g., Anderson, 1964; Block, 1960; Ekblaw, 1964). It is possible that some of the features described as kames are actually parts of eskers.

Little Rock Esker (#12) The Little Rock Esker is a short, low ridge located among Little Rock Creek in southern DeKalb County. The esker was extensively described by Leverett (1899). Although the esker has little elevation, it stands out against the low-relief terrain of the immediate region. Leverett mentioned that the local residents referred to it as the "Devel's Backbone". The western end terminates in a sandy tract covering 80 acres. Leverett thought that this tract may represent a delta. The maximum report thickness of sand and gravel within the esker is 15 feet.

Kaneville Esker (#13) The Kaneville Esker is the best known of the eskers of Illinois. Major discussions of it have been given by Leverett (1899) and Lukert and Winters (1965).

The Kaneville Esker has a total length of about seven miles. It is divisable into three topographically distinct sections. The southeast section was originally composed of several small, somewhat elongate hillocks that rose 20 to 50 feet in height. Quarrying has been extensive in the

southeast section with the result that little of the original form remains. The middle section consists of an elongate, irregularly crested ridge that is breached at several points. The ridge rises 40 to 70 feet above the adjacent plain, with increasing relief towards the northwest. The width ranges from 400 feet to more than 600 feet. The northwest section consists of a broad fan-shaped series of knolls which range from 50 to 70 feet in height. At their maximum they span a width of three-quarters of a mile. The northwest section was considered by Leverett (1899) and Leighton et al, (1931) to be a delta.

The materials of which the esker is composed are exposed in numerous quarries located in all three sections. The primary materials are sand and gravel. Dolomite clasts predominate. Locally deposits of silt and peat overlie the sand and gravel. These deposits apparently are fillings of depressions originally present on the esker.

Study of orientation of cobbles and direction of cross-bedding indicates that the flow of water responsible for forming the esker was directed toward the northwest (Lukert and Winters, 1965). This conclusion is reached in spite of the fact that the elevation of the esker increases in the same direction; the delta portion stands as much as 110 feet higher than the hillocks which comprise the southeast section. Apparently hydrostatic pressure was sufficient to drive the water up this slope (Lukert and Winters, 1965). Flow directed toward the northwest is also consistant with interpreting the northwest section as a delta.

Covel Creek Esker (#14) The Covel Creek Esker is located in LaSalle County about 5 miles south of Ottawa. It is a remarkably straight ridge about seven miles long and usually a little less than a quarter of a mile wide. Two gaps occur in the ridge, one near each end. The esker rises from 10 to 20 feet above the surrounding plain and is approximately symmetrical in shape. The crest is undulatory and rises in elevation from east to west through an elevation of about 40 feet. The eastern end of the esker is located on the Lake Ottawa plain, and the western end on the Farm Ridge ground moraine. The portion lying in the Lake Ottawa plain may have been covered at times by the waters of Lake Ottawa.

WOODFORDIAN ESKERS (YORKVILLE TILL)

Four eskers have been described from areas of the Yorkville Till. None of these are very long or topographically distinct. A discontinuous ridge which trends southwestward from near Central in Kendall County into north-central Grundy County may be a fifth Yorkville esker. This ridge was mapped by Culver (1923, Plate II) as "small hills of sand and gravel related to recessional stage of Marseilles ice." Ekblaw and Lamar (1964) also mapped it as either a kame trend or an esker. However, Willman and Payne (1943) and Willman (1970) considered the deposit to be a beach ridge which formed in the region at the margin of a post-Yorkville lake. The latter hypothesis is considered to be the more plausible interpretation. Another possible Yorkville esker consists of two elongate and aligned kamic hills located in western Will County (Sec. 4-5, T36N, R9E). The hills were mapped as kames by Fisher (1925), but their elongation suggests an eskerine origin.

Brookfield Esker (#15) The Brookfield Esker is a very short (1/5 mile) ridge located in Brookfield Township, LaSalle County. Although low and indistinct, the sand and gravel in it is at least 35 feet thick locally. The esker is located near the crest of the Marseilles Morainic System immediately south of the Illinois River Valley. Deep gullies which extend from the moraine into the valley have produced extensive local erosion. This erosion probably accounts for some of the indistinct topographic expression of the esker.

Wheatland Esker (#16) The Wheatland Esker was mapped and described by Fisher (1925). It is a short but conspicuous esker. Quarrying has extensively modified its original shape. The esker is located on the Minooka Moraine

Naperville Esker (#17) The Naperville Esker has been mapped and described by Fisher (1925). It consists of a series of five ridge segments which extend over a distance of one mile. The relief is low and the width rarely more than 300 feet. The esker is located on the Minooka Ground Moraine.

Warrenville Esker (#18) The Warrenville Esker was originally mapped and described by Trowbridge (1912). Although short and possessing low-relief, the esker has a sharply defined sinuous crest. It is divided into three segments by short gaps. The esker is located on the ground moraine of the Minooka drift.

WOODFORDIAN ESKERS (WADSWORTH AND HAEGER TILLS)

The Wadsworth Till region contains nine probable eskers. All are comparatively short, although several are sharply expressed. The recognition of the less-well expressed eskers is in part a reflection of the degree to which detailed mapping has proceeded in the Wadsworth Till region.

The region of eastern McHenry County and western Lake County contains a large number of kamic hills (e.g., Anderson and Block, 1962). The local till in this region is the Haeger Till (Willman and Frye, 1970), which is at least in part contemporaneous with the Wadsworth Till. Some of these kamic hills may be parts of eskers. The most likely candidate is a ridge of sand and gravel located in the Wonder Lake - Bull Valley lowland in eastern McHenry County (Sec. 24-25, T45N, R7E). The ridge appears to be an erosional remnant of adjacent blanket sand and gravel deposits, and hence not an esker. However, it is associated with some well-developed moulin kames and does possess the undulatory surface typical of an esker (IGS, Guide Leaflet 1952-D).

Orland Park Esker (#19) The Orland Park Esker is a mile long ridge of sand and gravel located at Orland Park in Cook County. Although Bretz (1943) mapped the feature as a ridge-form deposit, in his later work (Bretz, 1955) he did not apply the term esker to the ridge. A short (1/3 mile) sand and gravel ridge located one mile to the southwest of the main ridge may represent a continuation of the esker. Both ridges are located on the Westmont Moraine of the Valparaiso Morainic System (Willman and Frye, 1970).

Visitation Esker (#20) The visitation Esker is located immediately south of the Sag Channel Valley in southwestern Cook County. It is three-fourths of a mile long and sharply expressed, although not very high. The

crest is typically undulatory and its trace sinuous. The esker is located on the Clarendon Moraine of the Valparaiso Morainic System (Willman and Frye,1970).

Hickory Hills Esker (#21) The Hickory Hills Esker is a two-thirds of a mile long ridge located in the community of Hickory Hills. As shown on the map of Bretz (1943), the ridge has a sinuous course and relief of up to 25 feet. It is located on the Tinley Moraine. Local relief is high and the esker has evidently suffered considerable erosional modification.

Tiedtville Esker (#22) Bretz (1943; 1955) mapped, named, and described a short esker located north of the Des Plaines River Valley in southwestern Cook County. As described by Bretz, this esker is only a little more than a half-mile long. However, it occurs within a train of elongate kamic hills which extend both to the north and west of the esker. The west end of the kamic train lies within DuPage County. In aggregate the kamic trend extends for a distance of more than four miles. It is possible that the entire train represents a single esker building episode. Relief on the esker and the kame train reaches a maximum of 25 feet. The location of the esker and kamic knolls along the top of the Des Plaines River bluff was cited as evidence for a pre-Valparaiso depression at the position of the valley by Bretz (1955). The esker and knolls are themselves of Valparaiso age.

Oak Brook Terrace Eskers (#23) Two short eskers located within the corporate limits of Oak Brook Terrace in east-central DuPage County have been mapped by Bretz (1943) and later described by Bretz (1955). The larger of the two is only 2500 feet long and has a maximum height of only 15 feet. However, it has a well-defined s-shaped crest trace. The shorter esker, which is located three-quarters of a mile southwest of the longer has a length of about 1800 feet and a relief not exceeding 20 feet. Its ridge-form is indistinct. It is possible that the two ridges are a part of a single esker separated into two segments by a non-depositional gap. The Oak Brook Terrace Eskers are located on the Valparaiso Moraine (Willman and Fry, 1970).

Itasca Esker (#24) A narrow ridge of sand and gravel mapped by Ekblaw and Lamar (1964) at Itasca in northwestern DuPage County is probably an esker. The ridge is located in the valley of Spring Brook at a gap in the Palatine Moraine of the Valparaiso Morainic System (Willman and Frye, 1970). Its length is 1 1/2 miles and maximum height 30 feet.

Winfield Esker (#25) The Winfield Esker is a short esker described by Trowbridge (1912). It lies in the valley or the West Branch of DuPage River one mile west of Winfield. Its maximum height is 30 feet and its width 100 feet. The esker is situated in a sag which crosses the West Chicago Moraine.

Halfday Esker (#25) A half-mile long ridge located at Halfday in southern Lake County has been identified as an esker (Bretz, 1943 and 1955). The ridge has a subdued relief which does not exceed 15 feet. It is located in an area of ground moraine behind the Tinley Moraine. The esker probably formed under the ice which deposited this moraine.

Island Lake Eskers (#27) Two short but well-defined ridges located to the north and east of Island Lake in western Lake County probably represent eskers. Although not mapped in detail, these ridges have the characteristic

form of eskers. Gravel pits occur along the esker trend. A number of kamic hills occur nearby (Ekblaw and Lamar, 1964).

The longer of the two ridges extends for about 1 1/2 miles. The shorter ridge, which lies to the east of the longer, has a length of about one mile. If the two are considered as part of a single esker, the total length including the gap between the two is more than three miles. The highest part of the eskers occurs near the western end of the longer ridge. The eskers occur in the area of surficial Haeger Till.

CONSERVATION NOTE

The sand and gravel of which eskers are composed constitute a valuable mineral resource. As a result, many of the eskers of northern Illinois have been or presently are being extensively quarried. The end product of this quarrying is the destruction of the esker. As with other items of natural heritage, eskers are numerically limited. This realization and the attendant desire for at least a modicum of preservation of these features has spurred conservationists in many areas to protect eskers against destructive quarrying by the establishment of nature preserves, parks, and the like. None of the major eskers in Illinois have yet been so treated.

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THE COMPOSITION AND CHARACTERISTICS OF THE MOLLUSCAN FAUNA ASSOCIATED WITH THE PERRY MASTODON OF GLEN ELLYN, ILLINOIS

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ABSTRACT

The molluscan fauna associated with the Perry Mastodon is identified and quantitatively recorded. The environment of deposition was a late Pleistocene, cool-temperate, flood plain lake. Two extinct species were present, the remainder being modern forms.

The Perry Mastodon was found in 1963 in Glen Ellyn, Illinois during the excavation of some artificial lakes (Figures 1 and 2). The site is on the boundary of the flood plain of the DuPage River adjacent to the eastern slope of the Roselle Moraine of the Valparaiso Morainic System (Late Pleistocene). According to D. A. Block (1964) 120 bones from a single mastodon were recovered (distribution of large bones is shown in Figure 1). Picea tissue associated with the bones was dated at 10,980 BP ± 350 years. This approximately corresponds to the 11,000 BP boundary between the Valderan and Twocreekan Substages of the Late Pleistocene (Frye and Willman, 1960).

Willman (1971) mapped the site as Grayslake Peat (Formation). This unit characteristically is the result of lake filling processes in kettles, lake basins, and flood plain abandoned channels (Willman and Frye, 1970). The bedding at this site was gently dipping toward the northeast, apparently due to onlapping and probable compaction of the lake sediments upon the border of the Roselle Moraine. This would also account for an inclination of several feet across the dispersion area of the disarticulated bones. Slope wash would explain the presence of large dolomite pebbles in the silty muck. Irregularly distributed concentrations of marl were

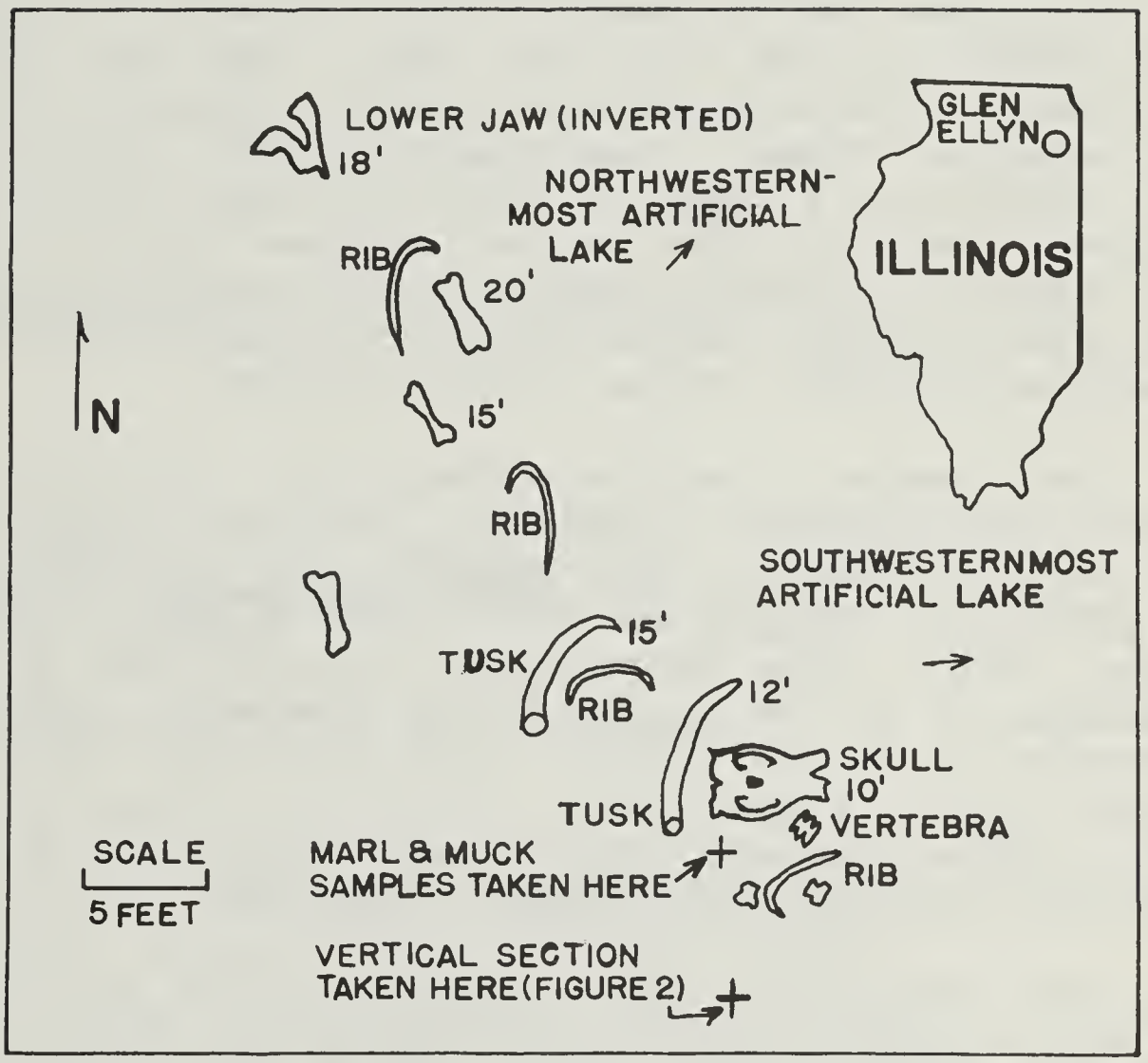

FIGURE 1. Sketch of Perry Mastodon excavation site showing the distribution of larger bones. Numbers indicate depth in feet.

found in the lower silty, organic muck. The marl consists of calcareous masses of Chara and gastropods.

Complete counts of mollusca retained by a #20 screen (0.84 mm.) were made for two samples taken adjacent to the mastodon skull (see Figure 2). One sample was marl. The other was a silty, organic muck. The most numerous species, Gyraulus altissimus, is restricted to "Wabash" assemblages by Baker (1920). Leonard and Frye (1960) give a range of Farmdalian and Woodfordian for this species. The only other extinct species found was Amnicola leightoni which is a common component of Pleistocene marls in the Midwest (Baker, 1928). Leonard and Frye restrict this species to Farmdalian Substage in the Illinois Valley.

Most species of mollusca identified are restricted to, or common in, lacustrine environments. Only one poorly-preserved specimen of a terrestrial form, Euconus (?), was found. Armiger crista and Stagnicola reflexa are restricted to small, shallow lakes (La Rocque, 1968). Some doubt exists as to whether or not Pisidium compressum is a lake species or is frequently washed into lake sediments (La Rocque, 1968). Little, if any, abrasion is present on the shells. Fragmentation of delicate forms is insignificant. Both of these characteristics would indicate no or limited transportation for the entire faunal assemblage.

Some species are currently found in the region, but others now have a more northerly distribution (La Rocque, 1968; Baker, 1928) (see Faunal List). Some species particularly of Amnicola appear to be somewhat stunted, which is common to mollusca in thermally depressed assemblages (Parmalee, 1968 in Bergstone).

The nature of the molluscan fauna plus the presence of Chara and Picea suggest a Late Pleistocene temperate climate somewhat cooler than the present local climate. The composition of the sediments and the fauna imply deposition in a flood plain lake.

FIGURE 2

Exposed Section Lombard Quad., Ill., T39N, R10E, NE1/4, Sec. 11 (for exact location see Figure 1).

Black humus	4'6"
Yellow clay	7"
Peat	3"
Light gray, non-fossiliferous, even-textured silt.	3"
Peat	1"
Gray-brown organic silt ("muck") with gastropods, Sphaerium, twigs, and dolomite pebbles.	3'8"
Light gray non-fossiliferous even-textured silt.	2"
Gray-brown organic silt ("muck"), with spruce wood, twigs, and cones, some charred wood and twigs, dolomite pebbles, large clumps of marl, small concretionary lumps of $CaCO_3$ and marcasite, H_2SO_4 gas, Chara, fish scales, ostracods, turtle scales. This unit is below the local water table.	6'0"

FAUNAL LIST

	PTI MUCK	PTI MARL
Acella haldemani Binney	0.05	----
Amnicola leightoni F. C. Baker	16.68	4.03
Amnicola lustrica Pilsbry	28.16	8.22
Armiger crista Linnaeus	0.29	0.70
Euconus (?)	0.05	----
Ferrissia parallela Haldeman	0.20	0.08
Fossaria dalli F. C. Baker	1.38	0.23
Gyraulus altissimus F. C. Baker*	27.53	44.18
Helisoma anceps striatum F. C. Baker	2.06	0.54
Mentus species	0.15	0.47
Pisidium casertanum Poli	0.34	----
Pisidium compressum Prime	1.03	1.32
Stagnicola reflexa Say	0.05	0.23
Valvata sincera Say	1.43	0.93
Valvata tricarinata Say	20.61	39.05
TOTAL	100.00	100.00

*Has more northerly distribution now.

"Muck" sample percentages based upon 2,038 individuals. Marl sample percentages based upon 1,288 individuals.

Additional species not occurring in quantitative samples but occurring in the section:

Anodonta species

Helisoma campanulatum Say

Helisoma trivolvis Say

Lymnaea stagnalis juglaris Say

Physa heterostropha Say

Sphaerium sulcatum Lamarck

All molluscan specimens will be kept by the Southern Illinois University Museum, Carbondale, Illinois.

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KALLSTROEMIA (ZYGOPHYLLACEAE) IN ILLINOIS

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ABSTRACT

The correct name for the Kallstroemia species which occurs in Illinois is K. parviflora Norton. Its distribution, spread, and disappearance in the state are discussed.

DISCUSSION

Jones and Fuller (1955), Jones (1963), Swink (1969), and Myers (1972) report the species of Kallstroemia known to occur in Illinois as K. intermedia Rydb. Kallstroemia intermedia, however, is a synonym of K. parviflora Norton, a species of disturbed areas in semiarid grasslands known from Colorado and Kansas south to central Mexico and west to Arizona (Porter, 1969a). Originally a semidesert plant, K. parviflora has been spread by man, first along the railroads and later along paved highways, to reach its present distribution. It has been spread eastward into disturbed habitats along railroad rights-of-ways and highways in Missouri (Porter, 1969b), Illinois, Mississippi, Maryland (Porter, 1970), and the District of Columbia (Hitchcock & Standley, 1919). Man also has dispersed K. parviflora to South America, where it is now a weed in western and central Peru.

Recent Illinois authors have indicated the comparative rarity of Kallstroemia parviflora in the state: "Railroad yards, occasional; adventive in Illinois. St. Clair Co., Eggert...." (Jones & Fuller, 1955, p. 299); "Railroad yards, occasional; adv. from southern U. S.; Blue Island, near Chicago, Cook. Co., Babcock; H. Eggert in St. Clair Co." (Jones, 1963, p. 101); "Introduced from the Southwest. In our area known only from Cook County, where it was collected before 1881 by Babcock along the Rock Island Railroad at Blue Island. His plant was a 'waif', and the species has no doubt long been absent from our living flora." (Swink, 1969, p. 230). The Babcock collection has not been seen, but the following Illinois specimens have been examined:

Cook Co.: Chicago, Moffatt 9507, 5 Sept 1896 (WIS); Brighton Park, Chicago, along C. & A. Railroad, Moffatt 458, 5 Sept 1896 (SMU, UC), waste ground, Umbach, 5 Sept 1896 (POM), dump, Umbach, 17 Aug 1897 (UC). Macoupin Co.: near Brighton, along C. & A. Railroad, Moffatt 498, 1 Sept 1893 (WIS). St. Clair Co.: Duste Platze, Eggert, Aug 1882 (MO). East St. Louis, Eggert, 8 Aug 1897 (PENN), Letterman, 24 July 1899 (MO), bones factory, Eggert, 8 Aug 1897 (DS, F, MO, NY, TEX, UC, US), B. & O. Railroad up island, Eggert, Aug 1884 (MO). Without locality (probably St. Clair Co.): Eggert, Aug 1882 (UMO); railroad dikes, Eggert, Aug 1882 (UC).

It is interesting to note that all the specimens cited were collected in the 19th Century from about 1881 to 1897. Kallstroemia parviflora apparently has not occurred in the state in this century.

Prior to the mid-1890's, weed removal on railroad rights-of-way was by hand, a time-consuming and expensive operation that also allowed seeds to be dislodged, germinate, and form more weeds. In 1894, probably the first weed-burning car was introduced by the Minneapolis, St. Paul, & Sault Ste. Marie Railway (Camp, 1904). Being more efficient and much less expensive to operate than hand-weeding, weed-burning cars rapidly took over that chore. Today, the latter have been supplanted by cars that spray diesel oil or other, more exotic, chemicals. It is probable that Kallstroemia parviflora was ommitted from the flora of Illinois as a result of this technological progress.

ACKNOWLEDGEMENTS

John H. White, Jr., of the National Museum of History and Technology, Smithsonian Institution, was most helpful in providing references on railroad right-of-way maintenance.

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ECTOPARASITES FROM MICROTUS OCHROGASTER, PEROMYSCUS LEUCOPUS, AND CRYPTOTIS PARVA IN COLES COUNTY, ILLINOIS[1]

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Abstract: Ectoparasites were taken from 50 white-footed deer mice, Peroymscus leucopus noveboracensis (Fischer), 50 prairie voles, Microtus ochrogaster ochrogaster (Wagner), and 11 least shrews, Cryptotis parva parva (Say), all collected within a five-mile radius from Charleston, Illinois, from 23 January 1973 through 25 June 1973. A total of 4,242 ectoparasites were recovered; 2,395 from M. o. ochrogaster, 542 from P. l. noveboracensis, and 1,305 from C. p. parva. The major groups of ectoparasites and their percent recovery were: Acari (excl. of Metastigmata) 81.5%, Metastigmata 2.5%, Anoplura 15.5% and Siphonaptera 0.5%. Eighteen families and 31 species of mites, 1 family and 1 species of tick, 1 family and 2 species of lice, and 2 families and 3 species of fleas were represented.

In recent years there has been an increase in the study of arthropod groups associated with non-domestic animals because of their importance as vectors and reservoirs of disease, as well as their natural importance as living organisms. Ectoparasites have been reported previously from small mammals in North America, however, little concerning the ectoparasites of small mammals in Illinois has been published. Records of ectoparasites of small mammals in Illinois include a general survey of the parasites of the cottontail rabbit by Ecke and Yeatter (1956),

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[1] based on a thesis by the senior author submitted in partial fulfillment of requirements for the degree of master of science at Eastern Illinois University

ecological notes on a few species of lice on the small mammals of Illinois by Verts (1960), and records of fleas from mammals by Layne (1958) and Verts (1961).

The present survey has intended primarily to identify and tabulate the ectoparasites of Peromyscus leucopus noveboracensis (Fischer), Microtus ochrogaster ochrogaster (Wagner), and Cryptotis parva parva (Say).

MATERIALS AND METHODS

The host mammals were trapped from 23 January 1973 through 25 June 1973 in Coles County, Illinois. The 111 host mammals were trapped in 50 standard museum special traps and 20 Sherman live traps, at five trapping areas within a five mile radius of Charleston. Microtus ochrogaster and P. leucopus specimens were trapped both dead and alive, while C. parva specimens were all trapped dead. All traps were baited with peanut butter and set flush to the ground, in or near runways. On cold days the Sherman traps were supplied with rags which acted as nesting material to prevent the freezing of the trapped animal. In each field the traps were set in lines 10 yds. apart. The traps were checked and baited daily, shortly after dawn, and on cold days in the evening as well.

Upon capture, the host specimens were placed in individual, labeled plastic bags to prevent loss of ectoparasites from drop-off, and to prevent host transfer by the ectoparasites (Cook, 1955). Specimens trapped alive were individually transferred to a one gallon jar, killed with chloroform, and then placed in plastic bags. Host specimens were placed in a freezer the day of their capture and left frozen until examined for ectoparasites.

Prior to the examination for ectoparasites each host was thawed in its plastic bag for approximately two hours. The host was then removed from the bag and placed in a 12 oz. jar for washing (Lipovsky, 1951). The bag was examined for ectoparasites with the aid of a dissecting microscope before the host was washed. Immediately after washing, the host was placed in a petri dish and examined for ectoparasites under a dissecting microscope using a dissecting probe to look through the animal's fur.

Ectoparasites were transferred from the bag, the host, and the wash water directly to individual microscope slides for identification, or to vials for storage. Ectoparasites to be stored were placed in 70% ethyl alcohol in specimen vials,

stoppered with cotton and placed in air-tight, labeled, storage jars. Three mounting media were used: Hoyer's, C.M.C. with acid fuchsin, and clear C.M.C. The slides were labeled with both host and ectoparasite data. The ectoparasites were identified with the aid of a compound microscope and a variety of specific taxonomic keys and papers.

RESULTS

A list of the ectoparasites which were recovered and their abundance is presented in Tables I, II and III.

DISCUSSION

The word "ectoparasite", as used in this and similar surveys, is misleading. A number of the recovered organisms listed in this paper do not express a true ectoparasitic relationship with the mammals. Because of the association of small mammals with vegetation in the form of stored food, nesting materials and runways, they are found accidentally to harbor phytophagous mites (Cryptostigmata, etc.). Other organisms listed here as ectoparasites are instead displaying a form of phoresis. Immature forms (deutonymphs or hypopi) of the Acaridia exhibit a phoretic relationship with other animals including small mammals, as shown in this survey by Dermacarus hypudaei (Table I) and Orycteroxenus soricis (Table III).

Few animal groups duplicate the enormous diversity in morphology, habitat and behavior seen in the Acari. Every terrestrial vertebrate group has its complex of external acarine parasites. Therefore, it is not surprising that 84 percent of the ectoparasites recovered in the present study were mites. The most common mite recovered was the phoretic species Orycteroxenus soricis (Table III). Hypopi of the genus Orycteroxenus have seldom been reported from North America because they are so small, and they cling tenaciously to individual hairs (Krantz, 1970). These characteristics of Orycteroxenus hypopi account for the inaccurate density reported for this group in many surveys as well as in the present (Table III). More accurate counts would be obtained only if the technique of digesting the host were used to recover the hypopi (Hilton, 1970).

Among the most abundant ectoparasite groups recovered in this survey was the genus Myocoptes (Table I, II). Besides the recovery of Myocoptes musculinus and Myocoptes japonensis (Fain and Hyland, 1970) a number of adults which possessed taxonomic

TABLE I - ECTOPARASITES RECOVERED FROM 50 MICROTUS OCHROGASTER IN COLES COUNTY, ILLINOIS

Taxonomic group	No. of hosts infested	% of hosts infested	Total no. of organisms	Density*
Acari				
Astigmata				
Glycyphagidae				
Dermacarus hypudaei	12	24.0	121	2.420
Listrophoridae				
Listrophorus leuckarti	7	14.0	97	1.940
Myocoptidae				
Myocoptes japonensis	21	42.0	52	1.040
Myocoptes musculinus	6	12.0	8	0.160
Myocoptes sp.	34	68.0	541	10.800
Cryptostigmata				
Brachychthoniidae				
Brachychthonius sp.	1	2.0	2	0.040
Oppiidae				
Oribella sp.	1	2.0	1	0.020
Mesostigmata				
Laelapidae				
Androlaelaps fahrenholzi	31	62.0	187	3.740
Laelaps kochi	44	88.0	461	9.200
Metastigmata				
Ixodidae				
Dermacentor variabilis	5	10.0	14	0.280
Prostigmata				
Ereynetidae				
Paraspeleognathopis sp.	2	4.0	2	0.040
Myobiidae				
Radfordia lemnina	25	50.0	140	2.800

TABLE I - ECTOPARASITES FROM MICROTUS (CONTINUED)

Taxonomic group	No. of hosts infested	% of hosts infested	Total no. of organisms	Density*
Pyemotidae				
Pseudopygmephorus sellnicki	3	6.0	3	0.060
Siteroptes absidatus	2	4.0	3	0.060
Tarsonemidae				
Tarsonemoides truncatus	4	8.0	45	0.900
Trombiculidae				
Euschongastia peromysci	3	6.0	7	0.140
Trombicula whartoni	7	14.0	38	0.760
Insecta				
Siphonaptera				
Hystrichopsyllidae				
Ctenophthalmus pseudagyrtes	10	20.0	16	0.320
Epitedia wenmanni wenmanni	1	2.0	1	0.020
Anoplura				
Hoplopleuridae				
Hoplopleura acanthopus	37	74.0	595	11.900
Total	50	100.00	2,395	47.900

*Density is determined by dividing total number of organisms by the total number of hosts examined.

TABLE II - ECTOPARASITES RECOVERED FROM 50 *PEROMYSCUS LEUCOPUS* IN COLES COUNTY, ILLINOIS

Taxonomic group	No. of hosts infested	% of hosts infested	Total no. of organisms	Density*
Acari				
Astigmata				
Glycyphagidae				
Dermacarus hypudaei	2	4.0	3	0.060
Acaridae				
Troupeavia sp.	3	6.0	5	0.100
Tyrophagus sp.	2	4.0	2	0.040
acarid nymphs	1	2.0	3	0.060
Anoetidae				
Prowichmannia spiniferum	1	2.0	2	0.040
Myocoptidae				
Myocoptes japonensis	3	6.0	6	0.120
Myocoptes musculinus	21	42.0	38	0.760
Myocoptes sp.	13	26.0	40	0.800
Saproglyphidae				
Calvolia sp.	1	2.0	1	0.020
Cryptostigmata				
Oribatellidae				
Zygoribatula sp.	1	2.0	1	0.020
Mesostigmata				
Ascidae				
nymph	1	2.0	1	0.020
Laelapidae				
Androlaelaps fahrenholzi	16	32.0	42	0.840
Haemogamasus sp.	1	2.0	1	0.020
Hirstionyssus arcuatus	7	14.0	21	0.420
Laelaps kochi	4	8.0	5	0.100
Phytoseiidae				
Typhlodromus sp.	1	2.0	1	0.020

TABLE II - ECTOPARASITES FROM PEROMYSCUS (CONTINUED)

Taxonomic group	No. of hosts infested	% of hosts infested	Total no. of organisms	Density*
Metastigmata				
Ixodidae				
Dermacentor variabilis	10	20.0	109	2.360
Prostigmata				
Myobiidae				
Radfordia subuliger	20	40.0	69	1.480
Pyemotidae				
Pseudopygmephorus sellnicki	1	2.0	1	0.020
Siteroptes absidatus	3	6.0	21	0.420
pyemotid male	1	2.0	1	0.020
Scutacaridae				
Scutacarus sp.	3	6.0	4	0.080
Tarsonemidae				
Tarsonemoides truncatus	3	6.0	5	0.100
Trombiculidae				
Euschongastia peromysci	11	22.0	83	1.660
Insecta				
Siphonaptera				
Hystrichopsyllidae				
Ctenophthalmus pseudagyrtes	1	2.0	1	0.020
Epitedia wenmanni wenmanni	6	12.0	8	0.160
Ceratophyllidae				
Orchopeas leucopus	3	6.0	5	0.100
Anoplura				
Hoplopleuridae				
Hoplopleura hesperomydis	15	30.0	63	1.260
Total	47	94.0	542	10.804

*Density is determined by dividing total number of organisms by the total number of hosts examined

TABLE III - ECTOPARASITES RECOVERED FROM 11 CRYPTOTIS PARVA IN COLES COUNTY, ILLINOIS

Taxonomic group	No. of hosts infested	% of hosts infested	Total no. of	Density*
Acari				
Astigmata				
Glycyphagidae				
Dermacarus hypudaei	1	9.1	1	0.090
Orycteroxenus soricis	11	100.0	1,255	114.000
Acaridae				
Tyrophagus sp.	1	9.1	1	0.090
acarid nymphs	2	18.2	2	0.180
Mesostigmata				
Laelapidae				
Androlaelaps fahrenholzi	1	9.1	1	0.090
Prostigmata				
Erythraeidae				
Erythraeoidea sp.	1	9.1	1	0.090
Myobiidae				
Blarinobia simplex	4	36.4	26	2.360
Protomyobia claparedei	5	45.5	13	1.180
Pyemotidae				
Pseudopygmephorus sellnicki	3	27.3	5	0.455
Total	11	100.0	1,305	119.000

*Density is determined by dividing total number of organisms by the total number of hosts examined.

characters not fitting the description of the known species were found and recorded as "Myocoptes sp." (Table I, II). Although it has been shown by Dubinina (1969) that two or more species of a single genus may coexist on the same host, the collection of two species and essentially intermediate forms from the same host in this investigation suggests the need for additional taxonomic work on the genus Myocoptes.

An acarine family known to contain a number of external parasites is Laelapidae. Of the laelapids collected, the cosmopolitan mite Androlaelaps fahrenholzi has been found to parasitize a variety of hosts (Baker et al., 1956), and was found on all three species of hosts examined in this survey. Another mite of this group, Laelaps kochi, was found clearly to illustrate a preference for M. ochrogaster (Table I). Hirstionyssus arcuatus was recovered only from P. leucopus and was recorded from Peromyscus by Whitaker and Wilson (1968) as Hirstionyssus talpae.

The members of the family Myobiidae are ectoparasites of rodents, marsupials, bats and insectivores (Krantz, 1970), and show a high degree of host specificity (Table I, II). Blarinobia simplex exhibited a high percent of infestation in this survey the only ticks recovered were nymphs of Dermacentor variabilis (Table I, II).

The major ectoparasitic group with the second greatest number of representatives recovered in this study was Anoplura. Due to the fact that anoplurans show a high degree of host specificity, two host groups were found infested with their own specific anopluran (Table I, II). Jameson (1947) also found that M. ochrogaster supported only Hoplopleura acanthopus.

The Siphonaptera make up the remaining 0.5 percent of ectoparasites recovered in the present study. Ctenophthalmus pseudagyrtes is the most common flea of small mammals and at the same time the least host specific (Benton and Cerwonka, 1960). The flea Orchopeas leucopus has shown a strong preference for P. leucopus (Table II), and this example of host specificity is supported by Layne (1958) and Verts (1961). Because most flea activity usually occurs within the den or nest of the host animal, and since fleas seldom oviposit on their host, selecting instead the confines of the host's nest, it was not surprising that few fleas were recovered.

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DNA SYNTHESIS AND EFFECTS OF HYDROXYUREA ON REGENERATING HYDRA

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Abstract Regenerating Hydra littoralis incorporate tritiated thymidine into DNA. The synthesis of DNA begins at least within six to eight hours following transection, and continues up to 24 hours. There is a decline in synthesis at 45 hours following transection, indicating possible metabolic turnover of DNA. Hydroxyurea (10^{-3}M) inhibits the synthesis of DNA by regenerating hydra, but inhibition is statistically significant only at the eight-hour period following transection. At eight hours there is an approximately 50% inhibition of DNA synthesis compared to 30% inhibition at 24 hours. At 45 hours inhibition is negligible, suggesting a possible breakdown of hydroxyurea or a completion of DNA synthesis at that time.

INTRODUCTION

The discovery that regenerating hydra incorporate tritiated thymidine into their cells (Burnett, Baird, and Diehl, 1962) provides a means by which the localization and extent of aspects of metabolic activity may be ascertained. The sequential pattern for cell renewal in hydra is as yet not fully known, but there is little doubt that a wide range of factors, both physiological and environmental, come into play. There is the indication of an overall decrease in catabolic activity during regeneration, and a lack of specific information by the regenerating hydra as to its anatomical completeness (Lentz and Barrnett, 1962).

In association with the decrease in metabolic activity is the synthesis of nucleic acids or precursors during regeneration. In the synthesis of nucleic acids necessary for cell replacement, hydra must either possess a reservoir of available constituents for this replacement or, upon transection or trauma, must form these constituents at a fairly rapid rate. Once the regenerative process is "triggered", there is an obvious need for utilizable organic substances from which the cells assemble the components necessary for the process.

The present paper deals only with the sequential synthesis of DNA with time in regenerating hydra, and with the effects of hydroxyurea on this activity.

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MATERIALS AND METHODS

Hydra littoralis were cultured in tap water containing $CaCl_2$, Na_2EDTA, CaCl, and TRIS buffer. Stock culture medium was renewed at least every ten days and kept at laboratory temperature of 22°C ± 2°C at pH 7.0. Hydra were fed Artemia nauplii daily and, at selected times, every other day for a 30- to 60-minute period. All animals used for experimentation were nonbudding, asexual organisms starved at least 48 hours prior to transection.

Deoxyribonucleic acid (DNA) extractions were made, utilizing fifty hydra transected through the lower stomach region and incubated for periods of 8, 24 and 45 hours in 9 ml of culture medium containing 1.0 ml tritiated thymidine (20 microcuries/ml). Identical procedure was followed for the inhibition experiments, except that a 10^{-3} M (0.076 mg/ml) solution of hydroxyurea in culture medium was used in place of culture medium alone.

In addition, groups of ten hydra were incubated for periods of 2, 4, 6, 8, 16, 24 and 45 hours in 1.8 ml of culture medium containing 0.2 ml tritiated thymidine, and the DNA extracted.

Following the incubation periods, the hydra were centrifuged and the medium decanted. Animals were washed three times, suspended in 10% trichloroacetic acid (TCA), and homogenized in the cold with a glass-teflon homogenizer. The homogenate was centrifuged for five minutes, and the pellet was treated with 1.0 ml of 0.6N KOH followed by an incubation period of 18 to 24 hours in a 37°C water bath. At the end of this time, 0.5 ml of 6N HCl and 1.0 ml of 10% TCA were added in the cold.

After precipitate formation, the homogenate was centrifuged for five minutes. The resulting pellet was washed and centrifuged three times in 2.0 ml of 5% TCA, resuspended in 2.0 ml of 10% TCA, and incubated in a 90°C water bath for 20 minutes to solubilize the DNA. The sample was then chilled in ice and centrifuged for five minutes, yielding the DNA supernatant fraction. This fraction was then counted by liquid scintillation for tritiated thymidine incorporation.

All samples -- 0.2 ml in 10 ml of dioxane-based scintillant -- were counted for ten minutes in a CPM-100 Liquid Scintillation Counter. Stock scintillant medium contained 5 grams of 2, 5-diphenyloxazole (PPO) and 100 grams of naphtalene made to 1,000 ml with dioxane.

RESULTS

Regenerating hydra, transected through the lower stomach region, display a definite pattern regarding the incorporation of tritiated thymidine into DNA. There is a relatively limited degree of incorporation during the first six hours, followed by a notable increase at the eight-hour period. There is continued increase in incorporation at 16 hours up until the apparent maximum is reached at about 24 hours. At this time, the organism must have at least the minimum amount of DNA required to further propagate the regenerative processes.

The decline in incorporation noted at the 45-hour period may indicate leakage or metabolism of the precursor as the regenerative processes have all but ceased, a loss of cells by the organism, or a metabolic turnover of DNA (Fig. 1).

FIG. 1. Incorporation of Tritiated Thymidine Into DNA of Regenerating Hydra (With Standard error)

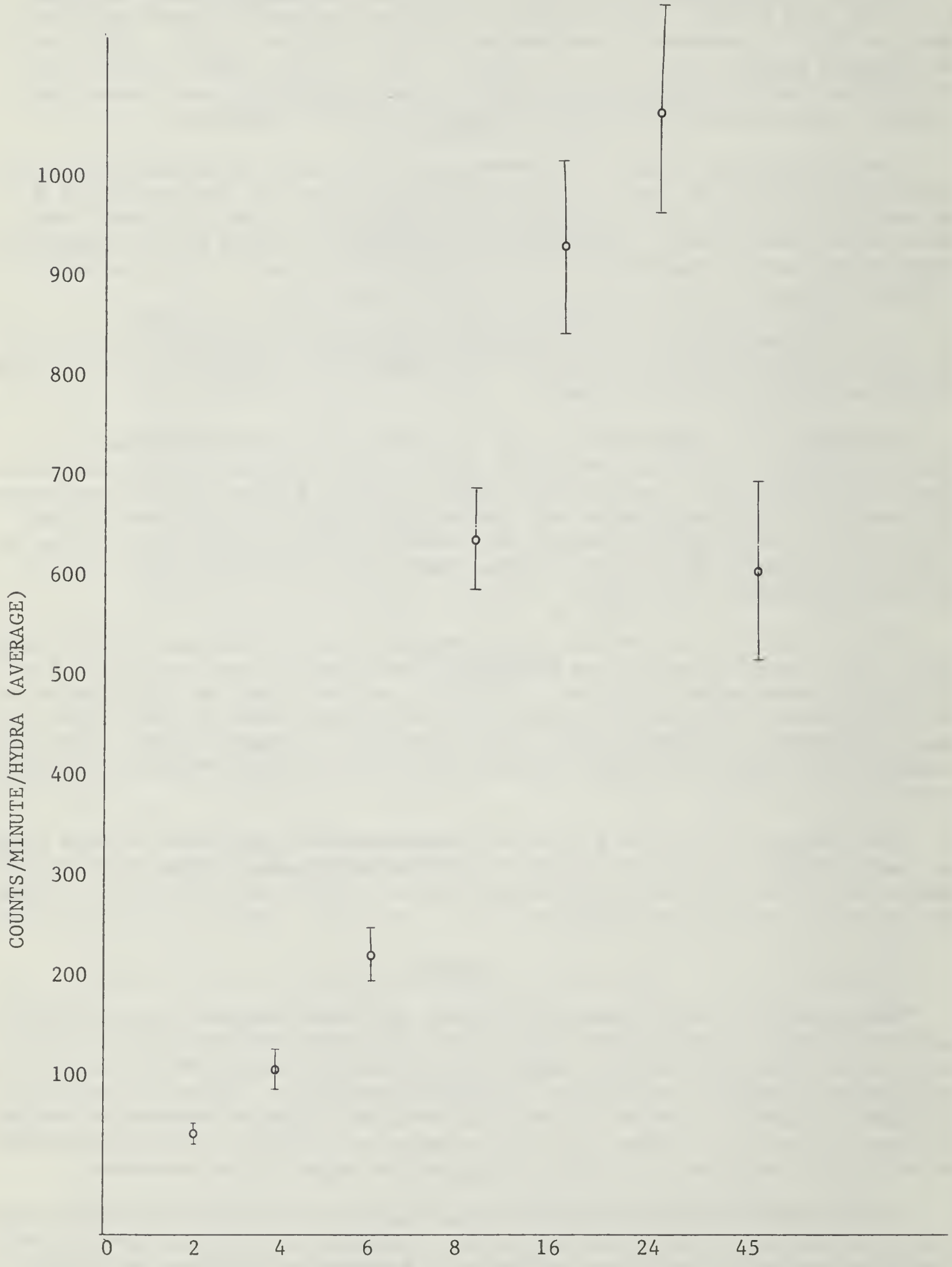
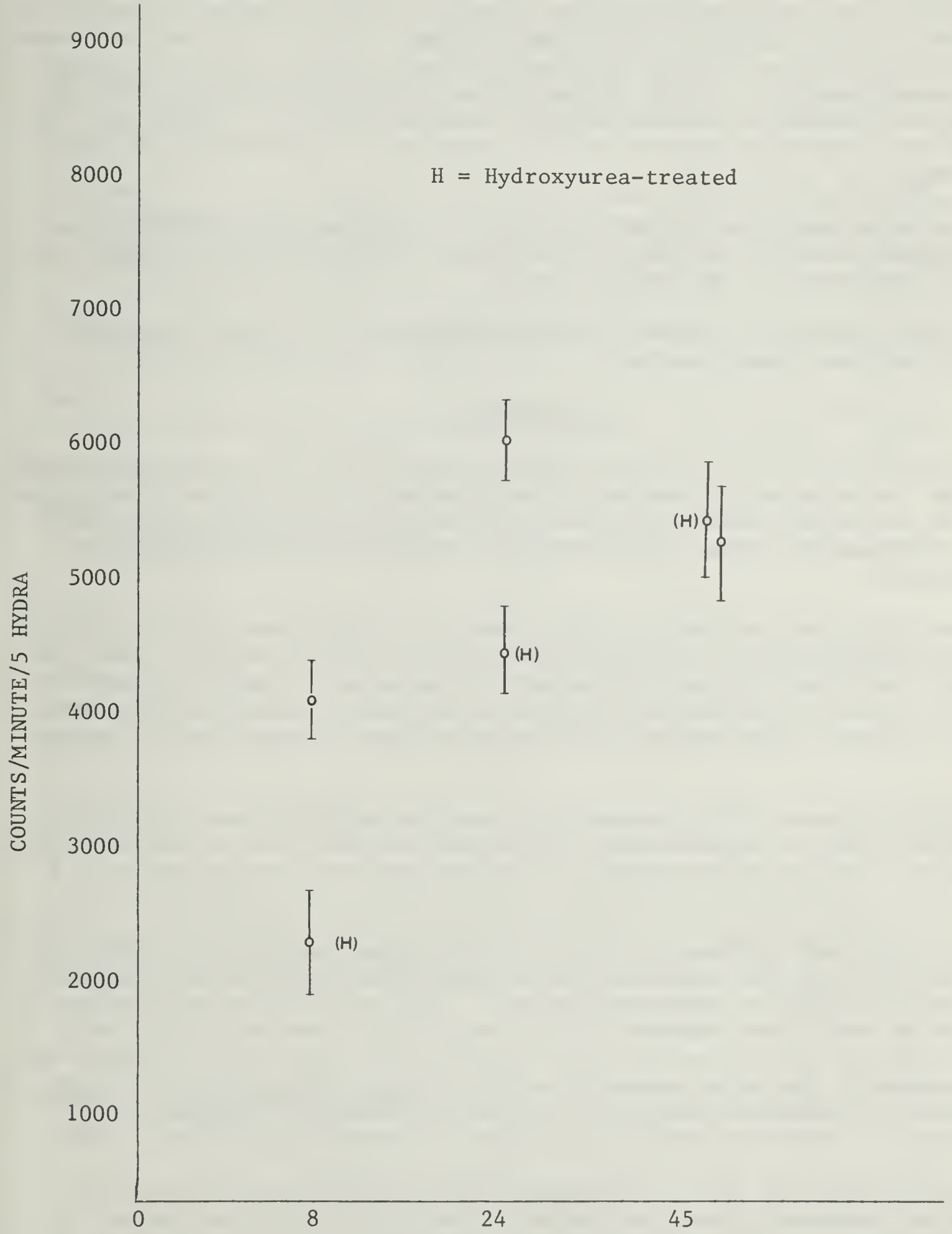


Fig. 2. Incorporation of Tritiated Thymidine into DNA of Hydroxyurea-Treated and Nontreated Regenerating Hydra at 8 hours, 24 hours, and 45 hours (with standard error)



The incorporation of tritiated thymidine into DNA of hydroxyurea-treated and nontreated regenerating hydra is shown in Figure 2. Counts per minute (CPM) at the eight-hour period show a range of from 3,900 to 4,800 for untreated organisms, and a range of 1,500 to 3,700 for hydroxyurea-treated organisms. At 24 hours the range is from 4,000 to 9,200 CPM for untreated animals, and from 1,700 to 8,100 CPM for treated animals. There is little detectable inhibition at 45 hours as the range of CPM is from 2,500 to 8,500 for untreated hydra, and from 2,400 to 8,400 for hydroxyurea-treated hydra. At each time period, however, the CPM for hydroxyurea-treated organisms are less than that for the corresponding untreated controls. There is thus blockage of isotope incorporation at the eight-hour period and 24-hour period. Results from the "t" test show that the inhibitory effect of hydroxyurea is statistically significant (.05 level) for the eight-hour period only.

There is an approximately 50% inhibition of synthesis at the eight-hour period compared with 30% inhibition at 24 hours. There is no determinable percentage of inhibition at the 45-hour period.

All data presented represent isotope incorporation into both proximal and distal sections taken together.

DISCUSSION

The incorporation of tritiated thymidine with time into regenerating hydra represents the relative progression of the synthesis of nucleic acids or precursors by the organism. This is predicated on the supposition that transection of hydra initiates the onset of synthesis of these materials, necessary for tissue renewal.

According to Ham and Eakin (1958), there is an eight-hour period following transection during which no visible differentiation can be observed, with the actual physical rebuilding of lost structures beginning at about the twelfth hour (Fig. 1) and the subsequent increase in synthesis corroborate these data and lend credence to the idea that DNA synthesis does increase during regeneration.

Work by Clarkson (1969) demonstrated that DNA synthesis was inhibited in hypostomes of hydra by approximately 60% during the first hour of distal regeneration, after a 20-hour pretreatment with hydroxyurea at a concentration of 1 mg/ml.

The significant inhibitory effect of hydroxyurea, noted at the eight-hour period (Fig. 2), may indicate that this is the period during which relatively larger amounts of DNA are being synthesized. That the relative percentages of inhibition by hydroxyurea between 8 hours and 45 hours are decreasing could indicate that the hydroxyurea is being metabolized or that there is completion of DNA synthesis. The major metabolic effect of this drug is reported to be a diminution in oxidative phosphorylation and a subsequent diminished total concentration of adenosine triphosphate (ATP) (Fishbein and Carbone, 1963).

From this base, it may be considered that available energy sources for hydra during regeneration are diminished by the action of hydroxyurea on the anabolic mechanisms. Evidence for this hypothesis is seen in the increased time required for hydroxyurea-treated hydra to complete fully the replacement of lost parts over that of nontreated organisms.

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OXYGEN AND PHOSPHATE METABOLISM OF BLUEGILL LIVER MITOCHONDRIA IN THE PRESENCE OF SOME INSECTICIDES

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ABSTRACT.--The effects of aldrin, carbofuran, chlordane, DDE, dasanit, diazinon, endrin, heptachlor, kepone, lindane, malathion, methoxychlor, parathion, thimet, sevin, and toxaphene on the oxidative phosphorylation by bluegill, Lepomis macrochirus, liver mitochondria in the presence of succinate and alpha-ketoglutarate as substrates were investigated. In the presence of succinate, chlordane, diazinon, heptachlor, kepone, malathion, parathion, thimet and toxaphene, severely inhibited oxygen uptake (57 percent malathion; 100 percent diazinon). The other insecticides did not alter oxygen uptake as severely (lindane 25 percent, endrin 49 percent) except dieldrin and carbofuran which did not affect oxygen uptake. All the insecticides inhibited oxygen uptake less in the presence of alpha-ketoglutarate than in the presence of succinate. Phosphate uptake did not appear to be altered by any of the insecticides. The data suggests a specific interaction of each insecticide with each bluegill liver oxidative enzyme complex.

Insecticides have been widely used for many years, and their effects have been extensively investigated; however, the modes of toxic action of most of the insecticides have not been elucidated (O'Brien 1967). Considerable data indicate that organochloro, organophosphate, and carbamate insecticides affect the nervous system (Metcalf 1957, O'Brien 1967). It is of interest, however, that while DDT has been shown to affect fish and bird reproduction in addition to having toxic affects on fish and birds, only recently has a mechanism of toxic action been suggested which can explain the diverse effects caused by DDT (Hiltibran 1971a).

We have been investigating the effects of possible pollutants on energy production by bluegill liver mitochondria, and have found that many derivatives of 2,4-dichlorophenoxyacetic acid (2,4-D) affected oxygen and phosphate uptake by bluegill liver mitochondria (Hiltibran 1969a, 1969b). Further, we have found that cadmium and zinc altered oxygen uptake, whereas manganese and calcium altered phosphate metabolism (Hiltibran 1971b).

Recently we investigated the effect of some insecticides on the oxygen and phosphate uptake by bluegill liver mitochondria and found that some insecticides severely inhibited oxygen uptake. We also investigated the effects of

insecticides on the hydrolysis of ATP (Hiltibran 1974b).

METHODS

Native wild bluegill from various bodies of water in central Illinois were held approximately two weeks at 25° C in aerated laboratory aquaria prior to use. Procedures for the preparation of the liver mitochondria, estimating the rate of oxygen and phosphate metabolism by conventional Warburg and spectrophotometric techniques, respectively, estimating the rate of release of inorganic phosphate from ATP and estimating the nitrogen content of the mitochondrial preparations have been reported (Hiltibran et al. 1965). Oxygen data were converted to microliter of O_2 per hour per milligram of tissue nitrogen (μl O_2/hr/mg N), and all phosphate data were converted to micromoles of PO_4 per hour per milligram of tissue nitrogen (micromoles PO_4/hr/mg N).

All values, corrected for endogenous enzyme activity, are the average values from three or more experiments. The standard deviation and range of values are also given. The insecticides used in this study were obtained from various sources and some were gifts from the manufacturers. Redistilled acetone or ethyl alcohol was used as a solvent. The effects of the insecticides were estimated at 10^{-4}, 10^{-6}, and 10^{-8} gram of insecticide per ml of reaction medium.

RESULTS

The effects of the various insecticides on the succinate oxidase and alpha-ketoglutarate oxidase are summarized in Tables 1 and 2 respectively.

The organochloro insecticide dieldrin and the carbamate insecticide, carbofuran, did not alter the oxygen or phosphate uptake in the presence of either substrate.

The remaining eight organochloro insecticides at a level of 10^{-4} g/ml altered oxygen uptake to various extents ranging from 25 percent inhibition in the presence of aldrin, to an inhibition of 87 percent in the presence of heptachlor. The organochloro insecticides did not alter phosphate uptake in the presence of succinate (Table 1).

All the organophosphate insecticides used in this investigation inhibited oxygen uptake. Dasanit inhibited oxygen uptake 38 percent, whereas diazinon completely inhibited oxygen uptake. The inhibition of the oxgyen uptake by bluegill liver mitochondria was more severe in the presence of the organophospate insecticides than in the presence of the organochloro insecticides. Phosphate uptake in the presence of succinate was not altered in the presence of the organophosphate insecticides.

The carbamate insecticide sevin inhibited oxygen uptake 35 percent and was the only carbamate insecticide to alter either oxygen or phosphate uptake in the presence of either substrate.

The organochloro insecticides, chlordane and heptachlor, inhibited oxygen uptake by bluegill liver mitochondria 39 and 29 percent, respectively in the presence of alpha-ketoglutarate (Table 2) and did not appear to have any effect on phosphate uptake. Lindane did not alter oxygen uptake but decreased the

TABLE 1. Effects of Insecticides on O_2 and PO_4 Uptake by Bluegill Liver Mitochondria in the Presence of Succinic Acid.

Insecticide	g/ml of reaction medium	Average change and standard deviation µl O_2/hr/mg N	µmoles PO_4/hr/mg N
		Organochloro	
Aldrin	3.7×10^{-4}	(-)58 ± 1.27 (14-106)	(±)12 ± 1.27 (6-17)
Chlordane	4.0×10^{-4}	(-)161 ± 1.38 (111-252)	(+)11 ± 1.20 (0-22)
DDE	3.2×10^{-4}	(-)81 ± 1.34 (8-170)	(±)18 ± 1.51 (3-38)
Endrin	3.8×10^{-4}	(-)100 ± 1.42 (23-148)	(+)8 ± 1.76 (0-34)
Heptachlor	3.7×10^{-4}	(-)233 ± 1.07 (125-326)	(±)18 ± 1.13 (11-29)
Kepone	4.9×10^{-4}	(-)216 ± 1.48 (106-459)	(±)14 ± 1.13 (7-23)
Lindane	2.9×10^{-4}	(-)76 ± 1.41 (41-129)	(±)32 ± 1.49 (3-105)
Methoxychlor	3.5×10^{-4}	(-)88 ± 1.44 (77-127)	(±)19 ± 1.44 (11-36)
Toxaphene	4.1×10^{-4}	(-)184 ± 1.15 (110-326)	(±)20 ± 1.12 (5-41)
		Organophosphate	
Dasanit	3.1×10^{-4}	(-)105 ± 1.21 (22-181)	(±)20 ± 1.42 (14-29)
Diazinon	2.9×10^{-4}	(-)260 ± 1.10 (194-344)	(±)44 ± 0.71 (35-53)
Malathion	3.3×10^{-4}	(-)141 ± 1.05 (74-214)	(+)24 ± 1.09 (2-41)
Parathion	2.9×10^{-4}	(-)208 ± 1.05 (106-301)	(+) 13 ± 1.15 (1-33)
Thimet	2.6×10^{-4}	(-)279 ± 1.04 (79-454)	(±)82 ± 1.35 (51-123)
		Carbamate	
Sevin	2.0×10^{-4}	(-)72 ± 1.31 (31-104)	(±)25 ± 1.24 (3-50)
Control		268 ± 1.56 (205-325)	43 ± 1.80 (29-82)

TABLE 2. The Effects of Insecticides on the O_2 and PO_4 Metabolism in the Presence of Alpha-ketoglutarate.

Insecticide	g/ml of reaction medium	Average change and standard deviation μl O_2/hr/mg N	μmoles PO_4/hr/mg N
		Organochloro	
Chlordane	4.0×10^{-4}	(-)35 ± 1.38 (14-66)	(±)15 ± 1.21 (2-32)
Heptachlor	3.7×10^{-4}	(-)31 ± 1.13 (3-50)	(±)8 ± 1.04 (1-15)
Lindane	2.9×10^{-4}	(±)19 ± 1.25 (14-26)	(+)7 ± 1.44 (0-20)
Methoxychlor	3.5×10^{-4}	(+)47 ± 1.50 (8-62)	(±)32 ± 1.28 (6-50)
		Organophosphate	
Diazinon	2.9×10^{-4}	(-)86 ± 1.19 (25-138)	(±)37 ± 1.49 (19-75)
Malathion	3.3×10^{-4}	(-)86 ± 1.28 (28-138)	(±)18 ± 1.35 (3-37)
Thimet	2.6×10^{-4}	(-)78 ± 1.44 (8-196)	(±)23 ± 1.16 (7-38)
Control		96 ± 1.39 (73-129)	27 ± 1.12 (12-41)

uptake of phosphate, whereas, methoxychlor increased oxygen uptake. The remaining organochloro insecticides did not alter either oxygen or phosphate uptake by the bluegill liver mitochondria.

Organophosphate insecticides, diazinon, malathion, and thimet inhibited oxygen uptake from 60 percent (thimet) to 88 percent (diazinon). Dasanit and parathion did not alter either oxygen or phosphate uptake. The carbamate insecticides carbofuran and sevin did not alter oxygen or phosphate uptake in the presence of alpha-ketoglutarate.

DISCUSSION

The results of previous investigations of the mode of action of the insecticides discussed by Metcalf (1955) and O'Brien (1967), indicates the organochloro, organophosphate, and carbamate insecticides interfere with nerve function. O'Brien (1967) further suggested that cyclodiene insecticides are not antienzymes, but indicated that definitive data are needed.

Johnson (1968), summarized the effects of insecticides on fishes, as damage to the central nervous system which resulted in instability, respiratory changes, and sluggishness. The chronic effects were residue accumulation, effects on reproduction, reduced growth rate, and gill damage.

Mount (1962) reported that endrin increased the oxygen consumption and ventilation rate of bluntnose minnow, whereas Huner et al. (1967) reported at low levels of endrin, oxygen uptake increased, whereas at higher concentrations, oxygen consumption decreased. DDT inhibited oxygen uptake by rat liver mitochondria (Johnston 1951), insect flight muscle mitochondria (Sacktor 1958, Anderson et al. 1954), and bluegill liver mitochondria (Hiltibran 1971a).

Lindane stimulated respiration and increased the respiratory rate of insects (Harvey et al. 1951). Chlordane, heptachlor, aldrin, dieldrin, and toxaphene increased the respiration rate of insects. Also, most of the increased respiratory activity was due to the hyperactivity after the application of insecticides (Metcalf 1955, O'Brien 1967). Further, it was suggested that death may be due to suffocation caused by the loss of nerve function.

Van Overbeek (1964) has defined a herbicide from physiological considerations as a chemical agent that deranges the physiology of the plant over a period long enough to kill the plant. Most toxic agents are chemicals and it would be reasonable to expect a chemical interaction between a toxic agent and the biochemistry of the organism. Thus, a toxic agent could be defined as a chemical which would alter the biochemistry of an organism to such an extent and for such periods of time that the physiology of the organism is severely altered and the organism dies. Such a definition of a toxic agent would also suffice to explain the chronic effects of toxic agents as well. The relationship between the biochemical effects of some phenoxy compounds, which had been used as herbicides, and their toxicity to bluegill have been discussed (Hiltibran 1969b, 1974a).

Rotenone, which is used as a fish toxicant and as an insecticide, is not a nerve poison (O'Brien 1967), increased respiratory activity in fishes. But, as the poisoning became more severe, it reduced frequency of breathing

rate, reduced oxygen uptake, caused loss of equilibrium, and death (Hiltibran unpublished data). However, fish treated with rotenone and removed to fresh water survived even after loss of equilibrium and reduced breathing rate (Bouck et al. 1965). Rotenone has been shown to reduce oxygen uptake in fishes (Danneel 1933) and grasshoppers (Tischler 1935). Later rotenone was thought to cause destruction of the gill tissue (Danneel 1933, Scheuring et al. 1935) and block the circulation in gill tissue (Hamilton 1941). Oberg (1959) reported that in severe rotenone poisoning, the circulation in the gills was normal and the destruction of the gill tissue was apparently due to secondary changes. Lindahl et al. (1961), studying the effect of rotenone on cellular respiration, reported that rotenone inhibited the uptake of oxygen in the presence of pyruvate and glutamate, but not in the presence of succinate. Similar results had been previously reported by Fukami (1954), Fukami et al. (1956), and Tomizawa et al. (1956).

Rotenone has been found to inhibit the flow of electrons between flavin adenine dinucleotide (FAD) and the cytochrome chain (Oberg 1961), and is the only biochemical action which has been demonstrated for rotenone. This would suggest that the specific biochemical effect described for rotenone may be of greater importance in the toxic action of rotenone than the previously described effects suggested. Rotenone severely inhibited the oxygen uptake by bluegill liver mitochondria (Hiltibran et al. 1965).

Antimycin A, used as a fish toxicant, inhibits the flow of electrons from substrate to oxygen, and apparently is the only known biochemical effect for antimycin A. Cyanide also has been used as a fish toxicant, and inhibits the flow of electrons from substrate to oxygen. The effects of antimycin A and cyanide on the uptake of oxygen by bluegill liver mitochondria has been discussed (Hiltibran 1965, 1967). These are the only known biochemical effects which have been shown for these fish toxicants, and would suggest some relationship between their inhibtion of oxygen uptake and their toxic action.

The mechanism of the toxic action of heavy metals to fishes is not known. Previously, the death of fishes was thought to be suffocation caused by coagulation of mucus on gill surfaces or damage to gill tissues (Doudoroff et al. 1953). This hypothesis was modified by Skidmore (1970) who suggested that tissue hypoxia was the cause of death of fishes after exposure to zinc. Data also cited by Doudoroff et al. (1953) indicated that the breathing rates and respiration rates of fishes increased in toxic metal solution, but oxygen consumption fell gradually until death, and the production of carbon dioxide declined. Other data cited by Doudoroff et al. (1953) indicated that some metals, which did not cause mucus to coagulate, may produce harmful effects.

Skidmore (1970) noted the decrease in oxygen utilization, increased gill ventilation volume, and decrease in heart rate, and the decline of PO_2 of dorsal aortic blood. Burton et al. (1972) reported that lactic acid accumulated in fish tissues after exposure to zinc and low oxygen levels, which would support the tissue hypoxia hypothesis suggested by Skidmore (1970). Hiltibran (1971b) reported that cadmium and zinc severely inhibited the uptake of oxygen of bluegill liver mitochondria. Bilinski et al. (1973) reported that cadmium and copper inhibited the oxidation of lactate by gill tissue of the rainbow trout.

The inhibition of oxygen utilization at the cellular level, as indicated

by the data of Bilinski et al. (1973) and Hiltibran (1971b) for cadmium, copper and zinc, would result in the accumulation of lactic acid, since it could not be metabolized via the Krebs tricarboxylic acid cycle due to the blockage of the oxidative systems by the heavy metals. The blockage of the oxidative systems by the heavy metals would reduce oxygen uptake, and decrease the production of carbon dioxide, observations that have previously been noted. The hyperactivity of insects and fishes in the presence of toxic agents would be the initial reaction of these organisms to the toxic agents and result in an increase in oxygen uptake. But, the effect which has been noted as poisoning became more severe, the decline in production of carbon dioxide at the cellular level would also cause a decrease in respiratory activity as indicated by a decrease in breathing rate activity, which also would reduce oxygen consumption. The hyperactivity would reduce the oxygen level of the blood, and what appeared to be tissue hypoxia as suggested by Skidmore (1970) and the data of Burton et al. (1973) would also indicate, would essentially be that oxygen utilization at the cellular level was blocked by the toxic agents such as heavy metals and the fish toxicants discussed above. Thus there is a cellular biochemical explanation of the physiological effects observed.

The cellular biochemical alterations caused by various toxic chemical agents to fishes have not been considered in any hypothesis of the mode of action of toxic agents, although it has been suggested (Hiltibran 1969b, 1971a, 1971b). But the possible cellular biochemical derangements, as indicated by the data in Tables 1 and 2 for the insecticides, could cause many of the physiological responses of fishes upon exposure of fishes to these toxic agents.

The inhibition of oxygen uptake of fishes by the insecticides would result in an increased activity and increased oxgyen utilization. But as the poisoning became more severe, there would be a decrease in oxygen utilization, a decrease in carbon dioxide production, a decrease in respiration rate, and finally death, physiological responses noted by various investigators.

Thus, it has been shown that most of the insecticides can severely alter the oxidative enzymes of bluegill liver tissues, as indicated by their effects on oxygen uptake of bluegill liver mitochondria, and that their toxic action could be mediated by their effects on these systems.

Further, since all the insecticides used interacted with each oxidative enzyme complex to different extents, it would suggest an interaction between each insecticide and each enzyme complex and that insecticides are not general enzyme inhibitors, or activators. Further support of this concept is indicated by the effect of these insecticides on the hydrolysis of ATP (Hiltibran, 1974b).

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CONSTITUTION AND BY-LAWS OF THE ILLINOIS STATE ACADEMY OF SCIENCE
(as of 27 April 1974)

CONSTITUTION

ARTICLE I. NAME

This Society shall be known as the Illinois State Academy of Science.

ARTICLE II. OBJECTS

1. The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the science interests of the state.

2. No substantial part of the activities of the Illinois State Academy of Science shall be devoted to any but scientific and/or educational objectives.

3. The net assets of the Illinois State Academy of Science shall be used for and only for, scientific and/or educational purposes and shall not in any way accrue to any group or private individual. The funded property shall be administered and operated in such manner that it will at all times maintain a tax exempt status under the provision of the United States Internal Revenue Code, both for income tax and gift tax purposes.

4. In the event of dissolution of this corporation all of its assets shall be distributed by the Council in accordance with Section 45 and/or Section 55(c) of the General Not For Profit Corporation Act - 1963, to one or more organizations exempt under Section 50 1(c)(3) of the Internal Revenue Code as here after amended or as it may be supplanted by the Internal Revenue Code for Income tax purposes.

ARTICLE III,

1. Any person or organization interested in the objects of the Academy upon payment of the appropriate dues to the Treasurer, shall become a member in good standing. In the case of contributing, or organizational memberships, the contribution is the amount remaining after substraction of regular dues. Any full time student who is certified as such by an advisor or instructor and upon payment of appropriate dues may become a student member with all rights and privileges of membership, except that of voting and holding office. An emeritus member shall be one who has been a member of the Academy for at least ten years and is retired (from his regular occupation). Individuals who attended the organization meeting of the Academy in 1908, paid dues for that year, and signed the original constitution of the Academy, are designated charter members.

2. Members who fail to pay dues for any fiscal year shall be considered in arrears for that year.

3. Regular individual members in good standing shall have the privilege of voting at the annual meeting, holding office, offering papers for presentation at meetings subject to the approval of the appropriate Section Chairman and with right of appeal to the Council, having papers published in the TRANSACTIONS if accepted by the Board of Editors, and receiving one copy of the current TRANSACTIONS of the Academy. No member in arrears shall receive the TRANSACTIONS for any year for which he is or remains in arrears.

4. The category of Honorary Memberships becomes a distinct category of memberhsip in the society.

ARTICLE IV. OFFICERS

1. A President, a First Vice-President, a Secretary , a Treasurer, and an Editor shall be elected by the members of the Academy at its annual meeting, shall hold office for one year or until their successors are elected and take office, and shall perform the duties usually pertaining to their respective offices. The First Vice-President shall also assist the Secretary in formulating the program for the annual meeting.

2. If between annual meetings of the Academy the offices of both President and First Vice-President shall become vacant, the last available Past President shall act as President until the next annual meeting. Interim vacancies in the offices of Secretary and Treasurer shall be filled by pro-tem officers elected by the Council.

3. A Second Vice-President, who shall preferably be a resident of the community in which the next annual meeting is to be held, shall be elected by the Council each year and shall serve as Chairman of Local Arrangements for that meeting. When possible, a Second Vice-President Elect, who shall preferably be a resident of the community in which the second next annual meeting is to be held, shall also be elected by the Council, subject to confirming election as Second Vice-President by the next succeeding Council.

4. The Director (or Acting Director) of the State Museum Division of the Department of Registration and Education of the State of Illinois, or a member of the State Museum Staff designated by the Director to represent him shall be the Librarian of the Academy and as such shall have charge of all books, collections, and similar property of the Academy, shall serve as archivist of all official records and documents of the Academy, and shall have charge of the distribution, sale and exchange of publications of the Academy, in accordance with policies determined by the Council.

ARTICLE V. COUNCIL

1. The Council shall consist of the President, First Vice-President, Second Vice-President, Secretary, Treasurer, Librarian, Editor, President of the Junior Academy, the immediate Past President, the immediate Past Secretary, the immediate Past Treasurer, each for a term of one year, and twelve Councilors-at-large. These last shall be elected to three year terms, four being elected each year until there are twelve.

2. Except as otherwise herein provided, the members of the Council shall be elected annually by the members of the Academy at its annual meeting and interim vacancies in these positions shall be filled by pro-tem elections by the Council. If and when a member of the Council does not attend any three meetings of the Council during an operating year, the position of that member will be declared vacant.

The Council shall manage the affairs of the Academy between annual meetings of the Academy and shall be responsible for the general planning, policies, program, and arrangements for annual meetings. It shall meet on call by the President ordinarily four times each year.

ARTICLE VII. MEETINGS OF THE ACADEMY

1. The regular annual meeting of the Academy shall be held at such time and place as the Council may designate. Meeting places shall be determined at least two years in advance.

2. Special meetings of the Academy shall be called by the President upon written request by ten per cent of the members.

3. No meeting of the Academy shall be held without 30 days previous written notice by the Secretary to all members.

ARTICLE VIII. JUNIOR ACADEMY

1. In order to foster science among youth, the Academy commits itself to cooperate with the Junior Academy in any way that the Executive Council of the Academy and Junior Academy find feasible.

ARTICLE IX. PUBLICATIONS

1. The regular publication of the Academy shall be the TRANSACTIONS OF THE ILLINOIS STATE ACADEMY OF SCIENCE.

2. Other publications may be authorized by the Council.

3. Paper presented at annual meetings of the Academy by non-members at the invitation or with the approval of the Council shall be eligible also for publication by the Academy.

ARTICLE X. BUSINESS AND FINANCE

1. Life membership payments shall constitute an inviolate endowment fund which shall be invested in guaranteed securities and of which only the income, in lieu of annual dues of the life members, shall be used by the Academy. Organizational membership payments and the contributions from the contributing membership payments shall be used to finance special activities of the Academy and to advance its program as shall be determined by the Council.

2. A second investment fund consisting of donations, bequests not otherwise restricted, allotments transferred by the Council from surplus reserve in the treasury, and similar sources shall be maintained as an emergency reserve, and only the income from this fund shall normally be available for the expense of the Academy.

3. The fiscal year of the Academy shall be from January 1 through December 31.

4. No expenditures may be made and no bills or other liabilities may be incurred by any officer, individual, or committee on behalf of the Acadmey, unless they are included in the budget, without prior approval of the Council.

5. At its second meeting each Council shall approve a budget of expenditures that shall not exceed the total of the current balance and the anticipated receipts, which budget may be modified by the Council at its subsequent meetings. The Treasurer shall not make payments for approved expenditures in excess of the covering item in the approved budget without express approval of the President and the Secretary. Such excesses must be covered by modifications of the budget at the next Council meeting.

6. The Secretary, Editor and Treasurer shall each receive an honorarium in amounts to be determined by the Council. These honoraria shall be paid by the Treasurer annually in April.

7. The President, the Secretary, and the Treasurer shall be reimbursed for their expenses while attending Council meetings and annual meetings. Other members of the Council may be reimbursed for their expenses while attending Council meetings other than those held in connection with annual meetings.

ARTICLE XI. AFFILIATIONS

The Academy may enter into such relations or affiliation with other organizatioms of appropriate character as may be recommended by the Council and approved by the members of the Academy at its annual meeting.

ARTICLE XII. AMENDMENTS

Proposed amendements to this constitution shall become effective upon approval by three-fourths of the members present and voting at the annual business meeting of the Academy, provided that notice of the proposed changes has been sent by the Secretary to all members of the Academy at least twenty days before such meeting.

BY-LAWS OF THE ILLINOIS STATE ACADEMY OF SCIENCE

I. ORDER OF BUSINESS

1. The Council shall ordinarily meet four times each year - once as soon as convenient after the annual meeting of the Academy, once each normally in November and February, and once just prior to the next annual meeting of the Academy.

2. Fifteen voting members shall consitute a quorum of the Academy and six members of the Council shall constitue a quorum of the Council.

3. The business meetings of the Academy and the meetings of the Council shall be conducted in accordance with Robert's Rules of Order.

II. DUES

1. The dues shall be as follows:

Regular member, annual.....	$ 7.50
Student member, annual.....	3.00
Life member, single payment.....	150.00
Contributing member, annual.....	15.00 or more
Organizational member, annual.....	150.00 or more
Emeritus member.....	No Dues

III. COMMITTEES AND DELEGATES

1. The standing committees of the Academy shall be Animal Experimentation in Research, Budget, Finance, Local Conventions, Membership, Research Grants, Science Talent, Contributing Memberships, and Science Teaching. Any of these committees may be abolished and additional ones may be established upon recommendation of the Council at any annual meeting of the Academy.

2. The chairmen and members of the standing committees shall be elected by the members of the Academy at its annual meeting. Interim vacancies on the committees shall be filed by the Council, who shall have authority also to elect additional members.

3. The Local Conventions Committee shall consists of the last three available Second Vice-Presidents and the Secretary of the Academy ex-officio.

4. There shall also be committees on Nominations and Resolutions of which the members shall be appointed by the President no later than 30 days following the annual business meeting. The membership of the Nominations and Resolutions committees shall be announced to the members of the Academy by the President or the Secretary no later than the second Council meeting following the annual business meeting.

5. The duties of the committeess shall be as defined by the Council, except as hereafter provided.

6. The budget committee shall submit at the last Council meeting for its consideration and for review at the annual meeting of the Academy a budget of anticipated income and recommended expenditures for the following year.

7. The Local Conventions Committee shall prepare and maintain up-to-date a"handbook" for the guidance of Second Vice-Presidents in discharging their duties as Chairmen of Local Arrangements and shall further advise such officers when requested.

8. The Nominations Committee shall present at the annual business meeting of the Academy a list of candidates for all offices and committees which shall be filled by election by members of the Academy.

9. The Resolutions Committee shall present at the annual business meeting of the Academy all resolutions for consideration by the members of the Academy, with the recommendations for or against approval. Members of the Academy who wish to sponsor resolutions shall submit them to the Resolutions Committee for consideration not less than 24 hours and preferably longer before the annual meeting. No resolution shall be presented at the meeting of the Academy unless it has first been submitted and approved by the Resolutions Committee. The Committee shall draft any appropriate resolutions as directed by the officers of the Academy or Council, may redraft any resolution submitted by any member or members to place it in more acceptable form, and may draft resolutions to incorporate suggestions offered by members of the Academy.

10. One or more delegates to the American Association for the Advancement of Science or to any other organization with which the Academy is affiliated,when such delegates are required, shall be elected by the Council for such a term or terms as the Council may designate.

IV. TECHNICAL SECTIONS

1. Technical papers presented at the annual meeting of the Academy will be distributed among Sections representing various fields of science as follows: Aquatic Biology; Anthropology; Botany; Chemistry; Collegiate Chemistry; Conservation; Geography; Geology; Meterology and Climatology; Microbionics; Physics; Science Teaching; and Zoology.

2. Any of these sections may be abolished, divided, or combined by the Council as seems desirable, and other sections may be established by the Council upon request of ten active members.

3. Members of the Academy should indicate in which section or sections they are particularly interested.

4. The members present at any section meeting during the annual meeting of the Academy shall constitute a quorum of the section. They shall elect a chairman for the ensuing year, who shall be responsible for assembling a program for the section for the next meeting. In the event that an elected chairman can not serve, a substitute shall be elected by the Council.

5. No paper shall be entitled to a place on the Section programs unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary in accordance with instructions. No paper shall be presented at any Section meeting by any person other than the author, except with approval of a majority of the members present at such meeting. No paper shall be accepted for publication unless the author or a co-author is a member of the Academy or an approved applicant for membership or unless it has been presented at the invitation of or with the approval of the Council, nor shall any paper published wholly or in large part elsewhere be acceptable for publication.

V. PUBLICATIONS

1. The publications of the Academy shall be under the supervision of a Committee on Publications, which shall consist of an Editor and a Board or Editors.

2. The Editor shall be appointed annually by the Council at its first meeting. He shall be chairman of the Committee on Publications and Technical Editor.

3. A Board of Editors, shall be appointed annually by the Editor, subject to approval by the Council, to assist the Editor.

4. Sometime between May 1 and September 1 of even-numbered years the Editor and/or the members of the Board of Editors shall confer with the Director of the Illinois State Museum concerning the amount of appropriations that should be requested for publication of the TRANSACTIONS during the next State Biennium.

VI. SUSPENSION OR AMENDMENT OF BY-LAWS

1. These by-laws may be suspended or amended at any annual meeting of the Academy by a majority vote of the members present.

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VOLUME 67 1974 No. 3

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SEPT.—1974

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INFRARED SPECTRA OF SOME ORGANOMETALLIC COMPOUNDS WITH TIN-COBALT BONDS

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ABSTRACT--The syntheses and infrared spectra of a series of compounds containing the (triphenylphosphinetricarbonylcobalt) derivatives of tin with general formulas $Y_{4-n}Sn[Co(CO)_3PPh_3]_n$ (where Y = Cl, Br, I, CH_3, C_4H_9, or C_6H_5 and n = 1, 2, or 3) are reported. The infrared spectra in the carbonyl stretching region of these compounds are discussed.

INTRODUCTION

Recently, there is a great deal of interest in organometallic compounds with metal-to-metal bonds. In the present work, a detailed study is made on a series of compounds containing the triphenylphosphinetricarbonylcobalt derivatives of tin. The compounds are prepared by one of the following methods: (1) Displacement of a neutral carbon monoxide molecule on a tetracarbonylcobalt derivative by triphenylphosphine, (2) Substitution of a chloride ion on tin by a triphenylphosphinetricarbonylcobalt anion, or (3) Insertion of an anhydrous tin(II) halide molecule into the triphenylphosphinetricarbonylcobalt dimer.

METHODS AND MATERIALS

All reactions were carried out under a static nitrogen atmosphere, and solid products were handled with minimum exposure to air. Tetrahydrofuran (THF) was purified by distillation from lithium aluminum hydride. Solutions of sodium triphenylphosphinetricarbonylcobaltate(I) were prepared by stirring THF solutions of triphenylphosphinetricarbonylcobalt dimer with excess 1% sodium amalgam for 10 to 12 hours.

The infrared spectra in the carbonyl stretching region were measured in 0.5 mm cells in methylene chloride solution using a

Perkin-Elmer 337 grating spectrometer and recorded on a Texas Instruments Serro-Riter with calibrations as described by Jetz (1966).

Microanalyses were performed by the Alfred Bernhardt Mikroanalytisches Laboratorium. Analytical data for the compounds are given in TABLE 1.

TABLE 1. Analytical Data.

COMPOUND	CALCD %			FOUND %		
	C	H	X	C	H	X
$Cl_3SnCo(CO)_3PPh_3$	40.02	2.40	16.87	40.83	2.71	15.85
$Cl_2Sn[Co(CO)_3PPh_3]_2$	50.44	3.02	7.09	50.70	2.91	7.08
$ClSn[Co(CO)_3PPh_3]_3$	55.22	3.31	2.60	55.73	3.73	2.47
$Br_3SnCo(CO)_3PPh_3$	33.03	1.98	31.39	34.94	2.36	30.37
$Br_2Sn[Co(CO)_3PPh_3]_2$	46.32	2.78	14.68	46.26	3.12	13.31
$BrSn[Co(CO)_3PPh_3]_3$	53.50	3.21	5.65	53.42	3.32	6.15
$I_3SnCo(CO)_3PPh_3$	27.88	1.67	42.08	27.34	1.94	43.13
$I_2Sn[Co(CO)_3PPh_3]_2$	42.64	2.56	21.45	42.20	1.93	20.48
$ISn[Co(CO)_3PPh_3]_3$	51.76	3.10	8.69	51.90	3.38	8.98
$Me_3SnCo(CO)_3PPh_3$	50.66	4.25	---	51.62	4.42	---
$Me_2Sn[Co(CO)_3PPh_3]_2$	55.09	3.78	---	56.19	3.94	---
$MeSn[Co(CO)_3PPh_3]_3$	56.96	3.58	---	56.78	3.91	---
$Bu_2Sn[Co(CO)_3PPh_3]_2$	57.56	4.64	---	57.25	3.97	---
$BuSn[Co(CO)_3PPh_3]_3$	57.83	3.91	---	58.64	4.14	---
$Ph_3SnCo(CO)_3PPh_3$	62.27	4.00	---	61.04	4.41	---
$Ph_2Sn[Co(CO)_3PPh_3]_2$	59.87	3.72	---	59.44	3.75	---
$PhSn[Co(CO)_3PPh_3]_3$	58.48	3.59	---	58.64	3.82	---

X = Cl, Br, or I.

Trichloro(triphenylphosphinetricarbonylcobalt)tin(IV), $Cl_3SnCo(CO)_3PPh_3$. Triphenylphosphine (0.065 g, 0.25 mmoles) was added to 0.1 g (0.25 mmoles) of $Cl_3SnCo(CO)_4$ dissolved in benzene. Vigorous CO evolution ensued and the solution was magnetically stirred for 20 min. Precipitation of solid occurred and this was completed by addition of hexane. The precipitate was recrystallized in benzene and precipitated by hexane. The tribromo and triiodo compounds, $Br_3SnCo(CO)_3PPh_3$ and $I_3SnCo(CO)_3PPh_3$, were similarly prepared.

Dichlorobis(triphenylphosphinetricarbonylcobalt)tin(IV), $Cl_2Sn[Co(CO)_3PPh_3]_2$. This compound was prepared by insertion reaction as described by Patmore (1966). The dibromo and diiodo compounds, $Br_2Sn[Co(CO)_3PPh_3]_2$ and $I_2Sn[Co(CO)_3PPh_3]_2$, were similarly prepared.

Chlorotris(triphenylphosphinetricarbonylcobalt)tin(IV), $ClSn[Co(CO)_3PPh_3]_3$. Anhydrous $SnCl_4$ (0.19 g, 1 mmole) and 1.22 g (1.5 mole) of $[Ph_3PCo(CO)_3]_2$, prepared by the method of Hieber (1957), were refluxed for 12 hours in 80 ml of dry THF. Solvent was removed at reduced pressure and the residue extracted with methylene chloride. Addition of *n*-pentane to the extract followed by cooling in dry ice-acetone mixture afforded red crystals. Recrystallization was done in methylene chloride and precipitated by *n*-pentane followed by cooling in dry ice-acetone mixture. The bromo and iodo compounds, $BrSn[Co(CO)_3PPh_3]_3$ and $ISn[Co(CO)_3PPh_3]_3$, were prepared in a similar manner.

Triphenyl(triphenylphosphinetricarbonylcobalt)tin(IV), $Ph_3SnCo(CO)_3PPh_3$. Triphenyl tin chloride (0.75 g, 2 mmole) was added to 100 ml of THF solution containing 4 mmoles of $Na[Co(CO)_3PPh_3]$. The reaction mixture was stirred at room temperature for 30 min. Solvent was removed at reduced pressure and the residue was extracted with minimum amount of methylene chloride. Slow addition of *n*-pentane followed by cooling in dry ice-acetone mixture gave pale yellow crystals. Recrystallization was done in methylene chloride followed by addition of *n*-pentane and cooling in dry ice-acetone mixture. $Me_3SnCo(CO)_3PPh_3$ was prepared in a similar manner.

Diphenyl-, dimethyl-, and dibutylbis(triphenylphosphinetricarbonylcobalt)tin(IV), $Ph_2Sn[Co(CO)_3PPh_3]_2$, $Me_2Sn[Co(CO)_3PPh_3]_2$, and $Bu_2Sn[Co(CO)_3PPh_3]_2$; and phenyl-, methyl-, and butyltris(triphenylphosphinetricarbonylcobalt)tin(IV), $PhSn[Co(CO)_3PPh_3]_3$, $MeSn[Co(CO)_3PPh_3]_3$ and $BuSn[Co(CO)_3PPh_3]_3$ were prepared by refluxing the corresponding tin chlorides in THF solutions of

$Na[Co(CO)_3PPh_3]$ for 30 min. The general procedure was the same as that for the $Ph_3SnCo(CO)_3PPh_3$.

RESULTS AND DISCUSSION

IR Spectra of Mono(triphenylphosphinetricarbonylcobalt) Derivatives. In compounds of general formula $Y_3SnCo(CO)_3PPh_3$, there are two structural possibilities. The triphenylphosphine group can be either *trans* to tin (C_{3v} point group) or *cis* to tin (C_s point group). In the former case, two IR-active modes are expected, (A_1 + E); in the latter case, three IR-active nondegenerate modes should be observed. It has been suggested by El-Sayed (1962) that, in any vibrational mode, the intensity should be proportional to the square of the vector sum of the local dipoles. Thus E modes are expected to be more intense than any nondegenerate A modes. Since only one intense broad band and a weak band at higher frequency are observed in all the carbonyl stretching region of the mono(triphenylphosphinetricarbonylcobalt) derivatives, the triphenylphosphine group is *trans* to tin. The selection rules enable assignment of the single intense band to the E mode and the weak band at higher frequency to the A_1 mode. The assignments of the mono(triphenylphosphinetricarbonylcobalt) derivatives in the carbonyl stretching region are summarized in TABLE 2.

TABLE 2. C-O Stretching Frequencies of $Y_3SnCo(CO)_3PPh_3$.

COMPOUND	A_1	E
$Cl_3SnCo(CO)_3PPh_3$	2058(0.2)	2009(10)
$Br_3SnCo(CO)_3PPh_3$	2058(0.3)	2005(10)
$I_3SnCo(CO)_3PPh_3$	2058(0.3)	2002(10)
$Ph_3SnCo(CO)_3PPh_3$	2015(0.5)	1956(10)
$Me_3SnCo(CO)_3PPh_3$	2015(0.3)	1946(10)

When the IR-active carbonyl stretching modes in $Y_3SnCo(CO)_3PPh_3$ and $Y_3SnCo(CO)_4$ are compared, the A_1 mode (C_{3v} point group) in

the former can be related to the $A_1^{(2)}$ mode (C_{3v} point group) in the latter (Patmore, 1967). When the spectra for the carbonyl stretching region of two analogous compounds are compared, it is observed that both the A_1 and E modes in $Y_3SnCo(CO)_3PPh_3$ are shifted to lower frequencies with respect to the $A_1^{(2)}$ and E modes in $Y_3SnCo(CO)_4$ and the relative intensities of A_1 to E in the former is much less than those of $A_1^{(2)}$ to E in the latter. The lowering in frequencies is due to the poor T-accepting property of the triphenylphosphine group as suggested by Graham (1968). The A_1 mode in $Y_3SnCo(CO)_3PPh_3$ and the $A_1^{(2)}$ mode in $Y_3SnCo(CO)_4$ are the symmetrical stretch of the equatorial carbonyl groups and should be almost IR-forbidden. The fact that the relative intensity of $A_1^{(2)}$ to E (C_{3v}) is much larger than that of A_1 to E (C_{3v}) suggests strong coupling between the $A_1^{(2)}$ mode and the $A_1^{(1)}$ mode in $Y_3SnCo(CO)_4$. The $A_1^{(1)}$ mode is the stretching vibration of the terminal CO group. When this terminal CO group is replaced by triphenylphosphine, no coupling can be expected.

IR Spectra of Bis- and Tris(triphenylphosphinetricarbonylcobalt) Derivatives. Assuming the equatorial arrangement of the carbonyl groups persists in the bis- and tris(triphenylphosphinetricarbonylcobalt) derivatives of tin, compounds of general formulas $Y_2Sn[Co(CO)_3PPh_3]_2$ and $YSn[Co(CO)_3PPh_3]_3$ have respectively C_{2v} and C_{3v} molecular symmetry. The group theory predicts five IR-active carbonyl stretching modes, $(2A_1 + 2B_1 + B_2)$, for the former class of compounds and also five IR-active modes, $(2A_1 + 3E)$, for the latter. In all the IR spectra of the compounds (TABLE 3 and TABLE 4), the predicted number of bands, including shoulders, are counted. Representative spectra are displayed in FIGURE 1 and FIGURE 2.

When the IR spectra in the carbonyl stretching region of similar compounds are compared, it is observed that the carbonyl stretching frequencies of compounds containing the $Co(CO)_3PPh_3$ group are shifted to lower frequencies with respect to compounds containing the $Co(CO)_4$ group, and that the two high energy bands for both the bis- and tris-$[Co(CO)_3PPh_3]$ derivatives are again smaller in relative intensities comparing with the corresponding compounds with $Co(CO)_4$ derivatives. Assignments for such complex spectra are difficult but it was suggested that the two high energy bands in all the bis-$[Co(CO)_4]$ derivatives are assigned the symmetric and asymmetric combination of the $A_1^{(2)}$

TABLE 3. C-O Stretching Frequencies of $Y_2Sn[Co(CO)_3PPh_3]_2$

COMPOUND	A_1(sym)	A_1(asym)	$2B_1 + B_2$		
$Cl_2Sn[Co(CO)_3PPh_3]_2$	2049(0.7)	2028(3.8)	2012sh(1.9)	1984(10)	1970(812)
$Br_2Sn[Co(CO)_3PPh_3]_2$	2046(1.0)	2028(4.9)	2012sh(2.4)	1984(10)	1972(8.0)
$I_2Sn[Co(CO)_3PPh_3]_2$	2043(0.7)	2025(5.3)	2012sh(1.4)	1983(10)	1970(8.0)
$Ph_2Sn[Co(CO)_3PPh_3]_2$	2025(0.7)	2009(2.0)	1962sh(9.7)	1953(10)	1940(7.6)
$Bu_2Sn[Co(CO)_3PPh_3]_2$	2022(0.3)	2007(0.7)	1960sh(8.7)	1953(10)	1942(5.5)
$Me_2Sn[Co(CO)_3PPh_3]_2$	2020(0.2)	2005(0.5)	1959sh(8.8)	1953(10)	1942(5.4)

TABLE 4. C-O Stretching Frequencies of $YSn[Co(CO)_3PPh_3]_3$

COMPOUND	A_1(sym)	A_1(asym)	3E		
$ClSn[Co(CO)_3PPh_3]_3$	2039(1.3)	2013(3.5)	1973sh(9.8)	1967(10)	1943(2.9)
$BrSn[Co(CO)_3PPh_3]_3$	2039(1.3)	2015(3.6)	1974sh(9.7)	1968(10)	1942(3.0)
$ISn[Co(CO)_3PPh_3]_3$	2038(1.3)	2016(3.5)	1974sh(9.8)	1968(10)	1943(3.2)
$PhSn[Co(CO)_3PPh_3]_3$	2038(1.2)	2018(2.6)	1975sh(9.6)	1968(10)	1957(7.9)
$BuSn[Co(CO)_3PPh_3]_3$	2035(1.6)	2015(2.9)	1972sh(9.6)	1965(10)	1951(7.1)
$MeSn[Co(CO)_3PPh_3]_3$	2035(1.0)	2015(2.5)	1970sh(9.5)	1962(10)	1950(7.0)

modes of the individual $Co(CO)_4$ group (Patmore, 1967). Observations in the present work for the bis-$[Co(CO)_3PPh_3]$ derivatives lends support to assignments by Patmore (1967). The band with the highest energy in bis-$[Co(CO)_3PPh_3]$ derivatives is assigned the symmetric combination of the A_1 modes of the individual

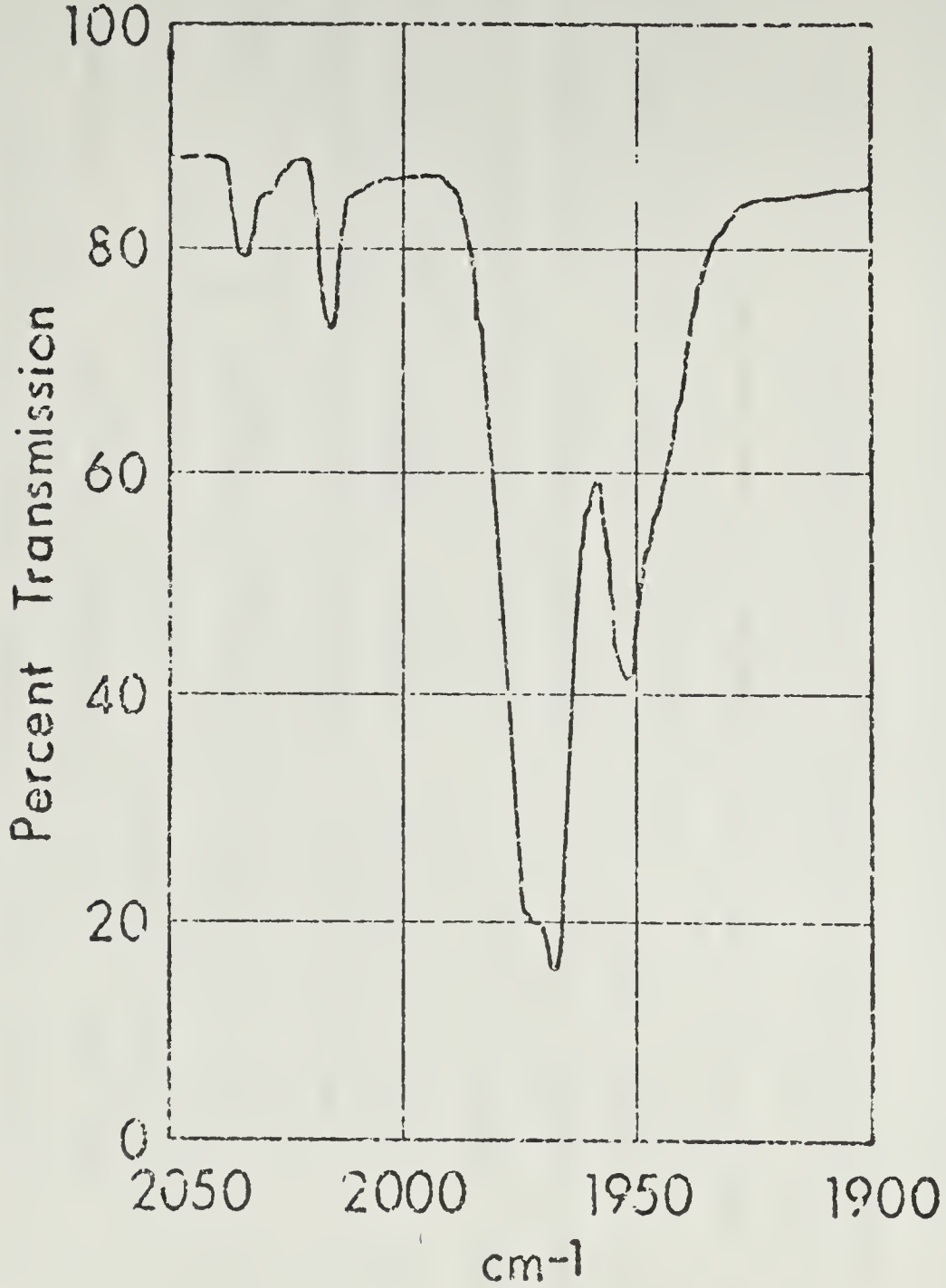

FIGURE 1. Infrared Spectrum of $Ph_2Sn[Co(CO)_3PPh_3]_2$.

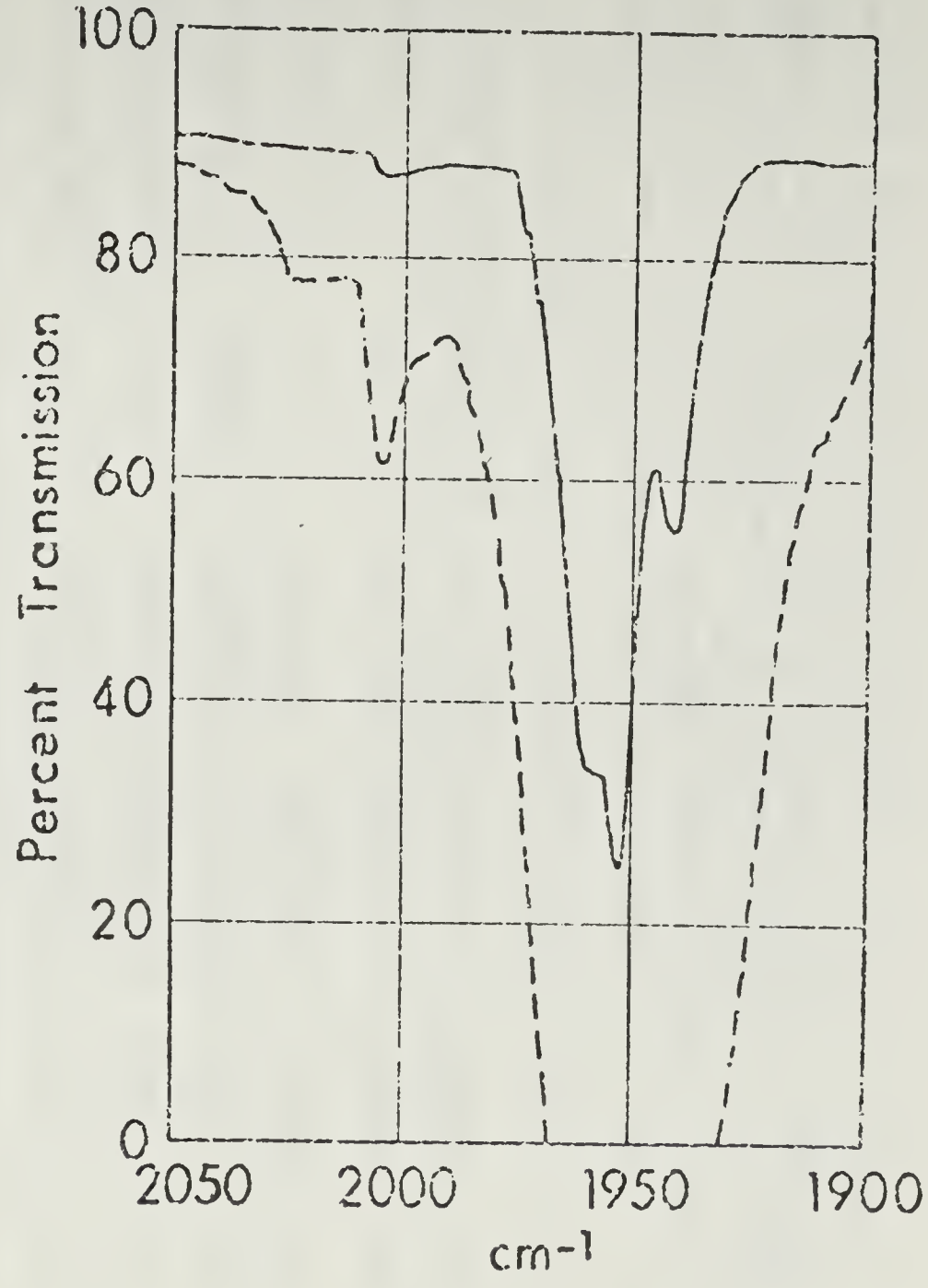

FIGURE 2. Infrared Spectra of $PhSn[Co(CO)_3PPh_3]_3$.

$Co(CO)_3PPh_3$ group and the band with the next highest energy is assigned the asymmetric combination of the A_1 modes, as illustrated in FIGURE 3. The two high energy bands in tris-$[Co(CO)_3PPh_3]$ derivatives are similarly assigned.

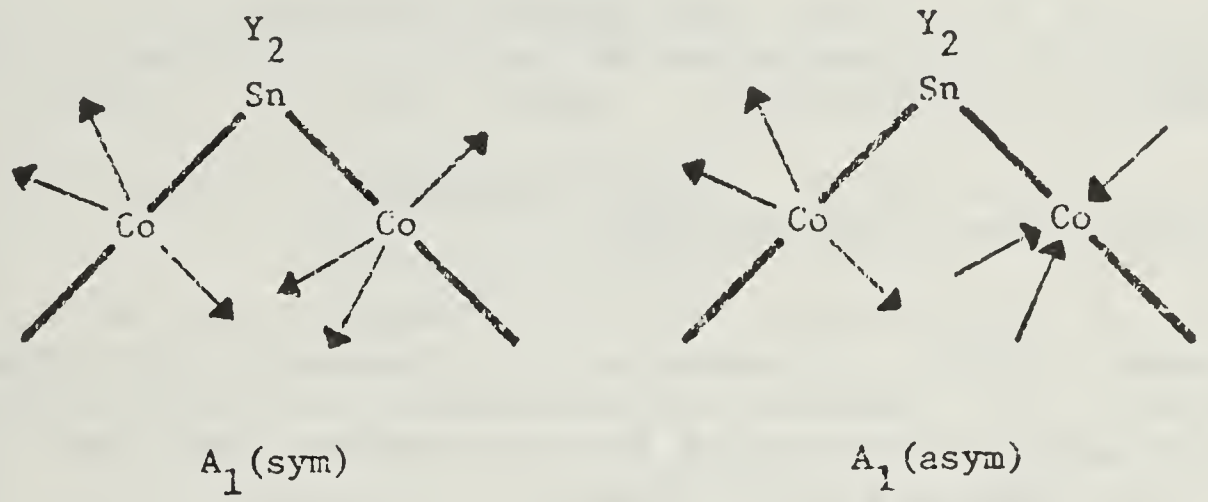

FIGURE 3. Symmetric and Asymmetric Combinations of A_1 Modes.

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THE INDIGENOUS DRUG PLANTS OF FULTON COUNTY, ILLINOIS

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ABSTRACT.—Discussion on the utilization of prehistoric man's natural environment has recently centered around problems relative to the subsistence base. For a variety of reasons involving, among others, the paucity of published archaeological evidence and the current emphasis on subsistence patterns, studies of non-food plants have been largely ignored. While it is conceded that food production was probably of primary importance to prehistoric man and that the relationship of man to food sources had a more dynamic effect on his culture, it is noted that many popular food plants also served a secondary role as medicine. Early botanical reports and recent research concerning the floristic environment in Fulton County, Illinois, reveal a wide variety of indigenous drug plants which have been used historically by both Indian and white populations. A cross-referenced alphabetical index of the common and binomial plant names is presented along with the part of the plant used, its preparation and supposed pharmacological action.

During a period from 1963-1965 the senior author implemented a study of the floral distribution of the Dickson Mounds area in the Central Illinois River Valley. This was done as part of a larger study concerning the burial population of Dickson Mounds (Harn 1971). The area considered was an approximate 5- by 5-mile transect along the western margin of the Illinois River beginning at a point opposite Havana, Illinois and continuing upstream. Spoon River borders its southern edge; Sister Creeks the north. The eastern border is formed by the Illinois River, while the western border parallels the Illinois. This region was selected because it offered the greatest variability in terms of natural environment. Examples of nearly all recognized types of vegetation zones in the central Illinois Valley occur in this 25-square-mile area.

The climate of the central Illinois Valley is temperate, with an average growing season of 177 days. Annual precipitation averages 34 inches, the average unmelted snowfall 20.9 inches. Hot summers and cold winters are common: mean monthly temperatures at Havana range from 26.6°F in January to 77.5°F in July. Concentrated spring rains frequently result in disastrous flooding and frequent late-summer droughts occur. Physiographically the Dickson Mounds area lies within the Galesburg Plain of the Till Plains Section of the Central Lowland Province; most of it in late youth in erosional cycle (Wanless 1957: 15).

The study area is located on the eastern edge of a region of gently rolling plains. These relatively flat uplands are deeply furrowed by numerous small upland stream valleys and washes. The bluffs bordering the Illinois and Spoon rivers on the west and north are 90- to 130-feet high and are mantled with a thick deposit of yellow-brown loess, while the east edge of the valley is defined by sand terraces, dunes and flat sand country. Alluvial fans sweep outward from the bluffs into the low valley, which is about four miles wide in this region. Terraces are situated between the bluffs and the floodplain. The broad, monotonous floodplain was originally a maze of large lakes and meandering channels, but much of the valley was leveed and drained during the land reclamation projects of the early 1900s. Only sloughs and pondlike areas remain.

The research area is situated near the boundary between the Prairie Peninsula section and the Mississippi Valley section of the Oak-Hickory Forest region (Braun 1950). Land surveys carried out in the early- to mid-1800s suggest that the dominant vegetational aspect of the area was treeless. Prairie prevailed on the uplands, broken only occasionally by open stands of forest, and was even found covering talus slopes and sizable portions of bottomland. Hardwood forests were limited to hillside talus-slope and bottom-land environments with limited forestation of upland stream valleys. Today the floodplain forest is usually confined to a belt bordering lakes, sloughs and river channels and their entering tributaries. A wide variety of trees, shrubs, herbaceous plants and grasses is represented in these zones (see Harn 1971: 5-7). Thus the region is characterized by a complex pattern of floristic communities composed of forest, woodland, savanna and grassland which--when combined with local landforms, water sources and the abundant fauna--provide the essentials required for optimum residential stability by prehistoric groups.

The original objective of the vegetational analysis was to attempt to isolate those plant species pertaining specifically to natural food, medicine, or technological resources and make a quantitative and spatial assessment of potentially desirable or usable floristic elements. It was hoped that this would provide the necessary framework for demonstrating the food and general habitation potential of the immediate Dickson Mounds area. However, research was severely hampered by a time factor imposed by the press of other duties and by the senior author's inability to rapidly identify the wide variety of flora in the field. Ultimately the more important aim of the entire work--the preparation of the manuscript dealing with the burial population--could not be ignored and the comprehensive floral analysis was abandoned. Only a summary of the data was presented (Harn 1971: 4-9).

The following is a listing of indigenous drug plants from the Dickson Mounds area, most of which were probably available to prehistoric people. This was in part compiled using information obtained from History of Fulton County, Charles Chapman & Co., Peoria, Illinois, 1879, History of Fulton County, (Bateman), Munnsell Publishing Co., Chicago, Illinois, (Heylin), 1908, and The Drug Plants of Illinois (Tehon 1951). No attempt has been made to assign these plants to separate medicinal categories or to identify them with the floristic habitat in which they are most dominant. The plants are listed alphabetically under both their scientific and common names; but the part of the plant used, its preparation and supposed pharmacological action are recorded under the scientific name only. Plants listed include official drug plants, formerly official drug plants, plants used by home or eclectic practitioners, plus plants whose use in remedies has been ethnographically documented within the eastern woodlands (see Tehon 1951 and Smith 1923, 1928, 1932 and 1933).

Coding of sources used:

1. Smith 1923
2. Smith 1928
3. Smith 1932
4. Smith 1933
5. Tehon 1951

Acer negundo L. Inner bark: emetic (2,3).

Acer saccharum Marsh. Inner bark: internal medicine (2). Wood: in a medicine mixture for woman with injured womb (2).

Achillea millefolium L. [incl. A. lanulosa Nutt.] Leaves: tea for fevers (1); poultice for rash of children (1); poultice for spider bites (3). Fresh tops: rub on eczema sores (1). Leaves and flowers: tea for fever and ague (2). Flowers: smudge to break fever (3), and as a reviver (4). Entire herb: astringent, diaphoretic, stimulant, and tonic (5).

Acorus calamus L. Root (rhizome?): cramps in the stomach (1); physic (1,2,3); chewed to relieve dyspepsia (1,2); powdered and snuffed up nose for catarrh (4); with other herbs to stop hemorrhage (4). Rootstock: aromatic bitter to aid digestion, and carminative (5).

Actaea alba (L.) Mill. Root: genito-urinary remedy for both sexes (2); tea for pain of childbirth (2).

Adiantum pedatum L. Leaves, stems, and roots: treatment of female maladies (1). Root (rhizome?): for the menses (2); stomach trouble (2); flux (2); tea for caked breast in nursing mother (4). Leaves: demulcent, pectoral (5).

Agastache scrophulariaefolia (Willd.) Kuntze Root: tea as diurient (2).

Alternate-leaved dogwood: Cornus alternifolia L.f.

Alumroot: Heuchera richardsonii R.Br.

Amaranthus retroflexus L. Pollen: antigen (5). Herb, root: astringent, detergent (5).

Ambrosia artemisifolia L. Pollen extract: prophylactic and cure for hayfever (5). Leaves and tops: topical astringent (5).

Ambrosia trifida L. Root: chewed to drive away fear at night (2). Pollen extract: prophylactic and cure for hayfever (5). Leaves and tops: topical astringent (5).

American elm: Ulmus americana L.

Amorpha cansecens Pursh Leaves: pinworms or any other intestinal worm (2).

Anemone, Meadow: Anemone canadensis L.

Anemone, Tall: Anemone virginiana L.

Anemone canadensis L. Root: cure for cross eyes (2); tea as eye wash when they twitch (2); throat lozenge (3).

Anemone virginiana L. Root: poultice for boil (1).

Antennaria plantaginifolia (L.) Hook. Leaves: tea to prevent sickness after childbirth (2).

Apocynum cannabinum L. Root: universal remedy for many things (2); dropsy and ague (2). Roots and rootstock: cardiac stimulant, cathartic, diaphoretic, diuretic, and emetic (5).

Aquilegia canadensis L. Root: for stomach and bowel troubles (2, 3); used with Zanthoxylum bark when bladder contents are thick (2). Roots and leaves: tea for diarrhoea (2).

Aralia racemosa L. Root: for blood poisoning (1); poultice for sores (1); tea for stomach ache (1); alterative, aromatic stimulant, and diaphoretic (5). Root pulp: hot poultice on inflammations (4).

Arisaema dracontium (L.) Schott Plant: treatment of female disorders (1).

Arisaema triphyllum (L.) Schott Root (corm?): pounded, as a poultice for sore eyes (1); reduce swelling from rattlesnake bite (2). Corm: diaphoretic, expectorant, irritant, and stimulant (5).

Aristolochia serpentaria L. Rhizome and root: aromatic bitter stimulant, and used with other drugs to increase their absorption and activity (5).

Arrow-head, Broad-leaved: sagittaria latifolia Willd.

Artichoke, Jerusalem: Helianthus tuberosus L.

Asarum canadense L. (sens. lat.) Root (rhizome?): mild stomachic (1, 4); sore throat (2); internal medicine (2); mixed with other things for stomach cramp (2); cooked and put in ear for earache or sore ears (2); chewed by sick person so that he can eat anything (3). Root and rhizomes: aromatic stimulant, carminative, tonic (5).

Asclepias incarnata L. Root: tea as taenifuge (2).

Asclepias syriaca L. Root: female remedy (3). Rootstocks and roots: diaphoretic especially in pulmonary and bronchial affections, diuretic, emetic, expectorant, purgative, and rheumatism (5).

Ash, Prickly: Zanthoxylum americanaum Mill.

Ash, White: Fraxinus americana L.

Aster, New England: Aster novae-angliae L.

Aster novae-angliae L. Entire plant: smudge as a reviver (2); fumigating agent (4).

Balsam-apple, Wild: Echinocystis lobata (Michx.) T. & G.

Baneberry, White: Actaea alba (L.) Mill.

Baptisia leucantha T. & G. Root: emetic (2); for eczema, sores (2); poultice for snake bite (2); tea for dropsy (2); internal medicine (2); boiled for catarrh (2); with sycamore bark on wounds made by axe or knife.

Basswood: Tilia americana L.

Bedstraw: Galium concinnum T. & G.

Bedstraw, Sweet-scented: Galium triflorum Michx.

Bellflower: Campanula americana L.

Bellwort: Uvularia grandiflora Sm.

Bergamot, Wild: Monarda fistulosa L.

Birdfoot-violet: Viola pedata L.

Bitternut Hickory: Carya cordiformis (Wang.) K. Koch

Bittersweet: Celastrus scandens L.

Black Cherry: Prunus serotina Ehrh.

Black-eyed Susan: Rudbeckia hirta L.

Black-haw: Viburnum prunifolium L.

Black Oak: Quercus velutina Lam.

Black Walnut: Juglans nigra L.

Black Willow: Salix nigra Marsh.

Blackberry: Rubus allegheniensis Porter

Blazing-star: Liatris aspera Michx.

Bloodroot: Sanguinaria canadensis L.

Blue Cohosh: Caulophyllum thalictroides (L.) Michx.

Blue Vervain: Verbena hastata L.

Bluebells: Mertensia virginica (L.) Pers. ex Link

Boneset: Eupatorium perfoliatum L.

Botrychium virginianum (L.) Sw. Plant: lung trouble and consumption (3).

Boxelder: Acer negundo L.

Bracken: Pteridium latiusculum (Desv.) Heiron. ex R. E. Fries

Broad-leaved Arrow-head: Sagittaria latifolia Willd.

Broad-leaved Goldenrod: Solidago latifolia L.

Bugleweed: Lycopus virginicus L.

Bur Oak: Quercus macrocarpa Michx.

Bush-clover: Lespedeza capitata Michx.

Buttercup: Ranunculus pennsylvanicus L.f.

Buttercup, Small-flowered: Ranunculus abortivus L.

Butternut: Juglans cinerea L.

Buttonbush: Cephalanthus occidentalis L.

Campanula americana L. Leaves: lung remedy (2); coughs and consumption (2).

Carya cordiformis (Wang.) K. Koch Bark: tea as laxative and makes the urine free (2).

Carya laciniosa (Michx. F.) Bark: cathartic (5).

Carya ovata (Mill.) K. Koch Bark: cathartic (5).

Cassia marilandica L. Seeds: soaked and eaten for sore throat (2). Leaflets: cathartic (5).

Cat-tail: Typha latifolia L.

Catchfly, Starry: Silene stellata (L.) Ait.f.

Caulophyllum thalictroides (L.) Michx. Roots (rhizome?): tea to suppress profuse menstruation (1, 2); genitourinary remedy for men (2); cramp during painful menstruation (3); tea for emetic (3); aids in childbirth (4). Rhizome and roots: alterative, diuretic, emmenagogue (5).

Cedar, Red: Juniperus virginiana L.

Celastrus scandens L. Inner bark: emetic (2); eczema sores (2). Berries: stomach trouble (3). Bark of root and stem: alterative, diaphoretic, diuretic, mild narcotic (5).

Cephalanthus occidentalis L. Inner bark: emetic (2). Bark: treatment of fevers (5).

Cherry, Black: Prunus serotina Ehrh.

Cherry, Choke: Prunus virginiana L.

Choke-cherry: Prunus virginiana L.

Cicely, Sweet: Osmorhiza longistylis (Torr.) DC.

Cicuta maculata L. Roots, rootstocks and seeds: in cases of barbital poisoning (5).

Cirsium discolor (Muhl.) Spreng. Root: tea for stomach ache (2).

Coffee-tree, Kentucky: Gymnocladus dioicus (L.) K. Koch

Cohosh, Blue: Caulophyllum thalictroides (L.) Michx.

Columbine: Aquilegia canadensis L.

Comandra umbellata (L.) Nutt. Leaves: tea for internal pains in the lungs (2).

Compass-plant: Silphium laciniatum L.

Coneflower, Drooping: Ratibida pinnata (Vent.) Barnh.

Coneflower, Pale: Echinacea pallida Nutt.

Coreopsis tripteris L. Stems: tea for internal pains and bleeding (2).

Cornus alternifolia L.f. Bark: pile and diarrhoea remedy (1). Inner bark: emetic (3).

Cornus racemosa Lam. [= C. paniculata L'Her.] Bark: tea (injected as an enema) to cure the flux (2, 3).

Corylus americana Walt. Bark: boiled for poultice for cuts (3).

Cow-parsnip: Heracleum lanatum Michx.

Cranesbill: Geranium maculatum L.

Culver's-root: Veronicastrum virginicum (L.) Farw.

Cup-plant: Silphium perfoliatum L.

Daisy-fleabane: Erigeron philadelphicus L.

Dicentra canadensis (Goldie) Walp. Tubers: alterative, diuretic, tonic (5).

Dioscorea villosa L. Root: relieve pain at childbirth (2). Rootstock: hemostatic and uterine sedative (5).

Diospyros virginiana L. Bark, unripe fruit: astringent in internal hemorrhage (5).

Ditch Stone-crop: Penthorum sedoides L.

Dogwood, Alternate-leaved: Cornus alternifolia L.f.

Dogwood, Gray: Cornus racemosa Lam.

Downy Phlox: Phlox pilosa L.

Drooping Coneflower: Ratibida pinnata (Vent.) Barnh.

Echinacea pallida Nutt. [= Brauneria angustifolia (DC.) Heller] Roots: cramps in stomach (2); alterative, diaphoretic, sialogogue, stimulant (5).

Elderberry, Common: Sambucus canadensis L.

Elm, American: Ulmus americana L.

Elm, Slippery: Ulmus rubra Muhl.

Elm-leaved Goldenrod: Solidago ulmifolia Muhl. ex Willd.

Equisetum arvense L. Whole plant: tea for dropsy (3); tea for kidney and bladder trouble and lumbago (4).

Equisetum hyemale L. Stems: tea for kidney trouble and to clear up the system after childbirth (1); tea for gonorrhea in men or women (2).

Erigeron annuus (L.) Pers. Herb: astringent, diuretic, tonic (5).

Erigeron canadensis L. Herb: astringent, diuretic, tonic (5).

Erigeron philadelphicus L. Disk florets: powdered and used as snuff to make one sneeze and thus break up a cold in the head or catarrh (2, 3). Flowers: tea to break fevers (3); dried flowers smudged to cure head cold (3).

Eryngium yuccifolium Michx. Root: for bladder trouble and poisons other than that of rattlesnake (2). Rootstock: diaphoretic, diuretic, expectorant, emetic (5).

Euonymus atropurpureus Jacq. Trunk bark: powdered for poultice on old facial sores (2). Inner bark: tea for bathing weak or sore eyes (2). Root bark: tea for bathing weak or sore eyes (2). Dried bark of stem and root: purgative (5).

Eupatorium perfoliatum L. Plant: tea for fevers (1). Foliage and flowers: tea to expel worms (2). Roots: snakebite (2). Herb: cathartic, diaphoretic, emetic, tonic (5).

Eupatorium purpureum L. Plant: diseases of the genito-urinary canal (1). Leaves: poultice for healing burns (4). Root: clear up after-birth (4); diuretic (5).

Eupatorium rugosum Houtt. [= E. urticaefolium Reichard] Plant: smudge as a reviver and steaming agent in sweat bath (2).

Euphorbia corollata L. Root: tea as physic (3). Rootstock: cathartic, diaphoretic, emetic (5).

Evening-primrose: Oenothera biennis L.

Everlasting, Sweet: Gnaphalium obtusifolium L.

False Solomon's Seal: Smilacina racemosa (L.) Desf.

False Toadflax: Comandra umbellata (L.) Nutt.

Fern, Maidenhair: Adiantum pedatum L.

Fern, Ostrich: Matteuccia struthiopteris (L.) Todaro

Fern, Sensitive: Onoclea sensibilis L.

Feverwort: Triosteum perfoliatum L.

Field Horsetail: Equisetum arvense L.

Field Mint: Mentha arvensis L.

Field Thistle: Cirsium discolor (Muhl.) Spreng.

Fleabane: Erigeron annuus (L.) Pers.

Fleabane, Daisy-: Erigeron philadelphicus L.

Flowering Spurge: Euphorbia corollata L.

Fragaria virginiana Duch. Root (rhizome?): tea for stomach ache, especially babies (3). Fruit: astringent, refrigerant, tonic (5).

Fragrant Sumac: Rhus aromatica Ait.

Fragrant Water-lily: Nymphaea odorata L.

Fraxinus americana L. Bark: infusion for sores and the itch (2). Inner bark of trunk and root: cathartic, diuretic, tonic (5).

Frost Grape: Vitis vulpina L.

Galium aparine L. Plant: tea as emetic (2); kidney trouble, gravel, stoppage of urine and allied ailments (3); diuretic (3). Herb: diuretic (5).

Galium concinnum T. & G. Plant: tea for bladder and kidney trouble (2); ague (2).

Galium triflorum Michx. Plant: infusion to clear up kidney trouble (1). Herb: nerve disorders (5).

Gentian, Yellowish: Gentiana alba Muhl.

Gentiana alba Muhl. [= G. flavida Gray] Root: tea as alterative (4).

Geranium maculatum L. Root (rhizome?): treatment of flux and like disorders (1); infusion for sore gums, pyorrhea and tooth ache (2); cure for neuralgia (2); poultice for piles and hemorrhoids (2); mixed with other things as a cure for diarrhea (2); for sore mouth (3). Rhizome: astringent (5).

Germander: Teucrium canadense L.

Giant Hyssop: Agastache scrophulariaefolia (Willd.) Kuntze

Giant Ragweed: Ambrosia trifida L.

Ginger, Wild: Asarum canadense L.

Ginseng: Panax quinquefolius L.

Glade Mallow: Napaea dioica L.

Gleditsia triacanthos L. Bark: tea in measles, fevers, smallpox, keeps bowels and kidneys free, hastens convalescence and prevents pitting (2). Bark of twigs: tea to cure bad colds (2).

Gnaphalium obtusifolium L. [= G. polycephalum Michx.] Plant: smudge to bring back loss of mind or to revive consciousness (2). Leaves and top: tonic (5).

Golden-seal: Hydrastis canadensis L.

Goldenrod: Solidago media (Greene) Bush ex Friesner

Goldenrod, Broad-leaved: Solidago latifolia L.

Goldenrod, Elm-leaved: Solidago ulmifolia Muhl. ex Willd.

Goldenrod, Rigid: Solidago rigida L.

Goldenrod, Showy: Solidago speciosa Nutt.

Goldenrod, Swamp: Solidago uliginosa L.

Goldenrod, Tall: Solidago altissima L.

Goosegrass: Galium aparine L.

Grape-fern: Rattlesnake: Botrychium virginianum (L.) Sw.

Grape, Frost: Vitis vulpina L.

Gray Dogwood: Cornus racemosa Lam.

Green Dragon: Arisaema dracontium (L.) Schott

Gymnocladus dioicus (L.) K. Koch Pod wax: cures insanity (2).

Hazelnut: Corylus americana Walt.

Hedeoma pulegioides (L.) Pers. Leaves and tops: aromatic, emmenagogue, stimulant (5).

Hedge-nettle: Stachys aspera Michx.

Helenium autumnale L. Flower heads: nearly mature, dried, pulverized and snuffed up nostrils to sneeze violently to loosen a cold in the head (1).

Helianthus strumosus L. Root (rhizome?): tea for lung trouble (2).

Heliopsis helianthoides (L.) Sweet [= H. scabra Dunal] Root (rhizome?): treatment of lung trouble (2).

Hemlock, Water-: Cicuta maculata L.

Hemp, Indian: Apocynum cannabinum L.

Hepatica acutiloba DC. Roots (rhizomes?): with Maidenhair-fern for various female maladies (1); tea to wash face to overcome some physical deformity (2). Leaves: tea to cure some physical deformity such as crosseyes (2).

Heracleum lanatum Michx. Root: colic and stomach cramps (2); pounded as a poultice for sores (3). Stem: poultice to heal wounds (2). Seeds (mericarps?): severe head pain (2).

Heuchera richardsonii R.Br. [= H. americana L.] Foliage: astringent in healing sores (2). Rootstock: topical astringent (5).

Hickory, Bitternut: Carya cordiformis (Wang.) K. Koch

Hickory, Shagbark: Carya ovata (Mill.) K. Koch

Hickory, Shellbark: Carya laciniosa (Michx. f.) Loud.

Honey-locust: Gleditsia triacanthos L.

Hop: Humulus americanus Nutt.

Hop-hornbeam: Ostrya virginiana (Mill.) K. Koch

Horehound, Water: Lycopus americanus Muhl. ex Bart.

Hornbeam, Hop-: Ostrya virginiana (Mill.) K. Koch

Horse-nettle: Solanum carolinense L.

Horsemint, Spotted: Monarda punctata L.

Horsetail, Field: Equisetum arvense L.

Horseweed: Erigeron canadensis L.

Humulus americanus Nutt. [= H. lupulus L.] Root: cure insomnia (2). Plant: tea acts like saleratus on the system (3).

Hydrangea, Wild: Hydrangea arborescens L.

Hydrangea arborescens L. Roots: diaphoretic, diuretic (5).

Hydrastis canadensis L. Root: for eczema (2); inhalant for catarrh (2). Leaves and rootstock: tonic to mucous membrane, principally in catarrhal affections (5).

Hydrophyllum virginianum L. Root: keep flux in check (3).

Hyssop, Giant: Agastache scrophulariaefolia (Willd.) Kuntze

Impatiens biflora Walt. Plant (fresh): poultice for sores (2). Fresh juice: neutralize sting of nettles (2, 4); aleviate itching of poison ivy (4); rubbed on head to cure headache (3). Whole plant: infusion cures colds in the chest or cramps in the stomach (4); boiled down to give liniment for sprains, bruises, and soreness (4).

Indian Hemp: Apocynum cannabinum L.

Indian-tobacco: Lobelia inflata L.

Indian-turnip: Arisaema triphyllum (L.) Schott

Indigo, White: Baptisia leucantha T. & G.

Iodanthus pinnatifidus (Michx.) Steud. Whole plant: poultice for the head, brings warmth to body of old cold man (2).

Ipomoea pandurata (L.) Meyer Root: purgative (5).

Ivy, Poison: Rhus radicans L.

Jacob's-ladder: Polemonium reptans L.

Joe-Pye-weed: Eupatorium purpureum L.

Juglans cinerea L. Sap: syrup and sugar a physic (1). Twig bark: tea as cathartic (2). Wood: tea as cathartic (2). Bark: physic (4); cathartic (4). Inner bark: infusion for tonic effects (4). Leaves and root bark: mild cathartic (5).

Juglans nigra L. Inner bark: strong physic (2). Twig bark and old bark : coiled, charred, and applied for a snake bite (2). Hulls of fruits: pile medicine (2). Inner bark of root, leaves: mild cathartic (5).

Juniperus virginiana L. Inner wood: inhalant for catarrh (2). Leaves: tea for weakness and as convalescent medicine (2). Berries: remedy for interior troubles, for lungs and for fevers (2). Wood: oil from wood a rubefacient (5).

Kentucky Coffee-tree: Gymnocladus dioicus (L.) K. Koch

Lactuca canadensis L. Plant: fresh juice rubbed on poison ivy eruptions (1).

Laportea canadensis (L.) Gaud. Root: diuretic (3).

Lead-plant: Amorpha canescens Pursh.

Lepidium virginicum L. Whole plant: tea as a wash for poison ivy (1).

Lespedeza capitata Michx. Root: antidote for poison (2).

Lettuce, Wild: Lactuca canadensis L.

Liatris aspera Michx. [= L. scariosa Willd.] Plant: bladder and kidney trouble (2).

Liverleaf: Hepatica acutiloba DC.

Lobelia inflata L. Leaves and tops - dried: antispasmodic in laryngitis and spasmodic asthma, emetic, expectorant (5).

Locust, Honey-: Gleditsia triacanthos L.

Lycopus americanus Muhl. ex Bart. Whole plant: mixed with other things for cramps in stomach (2).

Lycopus virginicus L. Herb: astringent, narcotic, sedative, tonic (5).

Maidenhair-fern: Adiantum pedatum L.

Mallow, Glade: Napaea dioica L.

Maple, Sugar: Acer saccharum Marsh.

Matteuccia struthioperis (L.) Todaro [= Onoclea struthioperis (L.) Hoffman]
Leaves: poultice (1). Root (rhizome?): tea for whitish urine (1).

May-apple: Podophyllum peltatum L.

Meadow anemone: Anemone canadensis L.

Menispermum canadense L. Rhizome and roots: alterative, diuretic, tonic (5).

Mentha arvensis L. (sens. lat.) Plant: poultice on the chest (1); with other species in tea for pneumonia (1); blood remedy (3); tea to break fevers (3). Leaves: treating fevers (4); tea for curing pleurisy (4).

Mertensia virginica (L.) Pers. ex Link Plant: tonic (5).

Milkweed, Common: Asclepias syriaca L.

Milkweed, Swamp: Asclepias incarnata L.

Mint, Field: Mentha arvensis L.

Mirabilis nyctaginea (Michx.) MacM. [= Oxybaphus nyctaginea (Michx.) Sweet]
Whole plant or root: for bladder troubles (2); poultice for burns (2). Root: reduce sprains and swellings (3).

Monarda fistulosa L. Leaves and flowers: tea for catarrh (1). Plant: combined with other species for cold cure (2); boil, then inhale steam to cure catarrh and bronchial affections (3).

Monarda punctata L. Leaves: used in mixtures for its aromatic principles (2). Leaves and flowers: aromatic, diaphoretic and stimulant (5).

Moonseed: Menispermum canadense L.

Morus rubra L. Root bark: any sickness (2).

Mulberry, Red: Morus rubra L.

Nannyberry: Viburnum lentago L.

Napaea dioica L. Roots: for piles (2); remedy for female troubles (2).

Nettle: Urtica gracilis Ait.

Nettle, Hedge-: Stachys aspera Michx.

Nettle, Horse-: Solanum carolinense L.

Nettle, Wood: Laportea canadensis (L.) Gaud.

New England Aster: Aster novae-angliae L.

Nuphar advena (Ait.) Ait.f. [= Nymphaea advena Ait.] Rhizome: powdered and used for poultices to heal cuts and swellings (1); powdered to heal cuts and swellings (3). Root (rhizome?): grated to make poultice for sores (3); for inflammatory diseases (4).

Nymphaea odorata Ait. [= Castalia odorata (Ait.) Woodv. & Wood] Root (rhizome?): remedy for eczema (2); cough medicine for those who have TB (3). Rhizome: astringent (5).

Oak, Black: Quercus velutina Lam.

Oak, Bur: Quercus macrocarpa Michx.

Oak, Red: Quercus rubra L.

Oak, White: Quercus alba L.

Oenothera biennis L. Whole plant: soaked in warm water to make poultice for bruises (3).

Onoclea sensibilis L. Root (rhizome?): powdered - tea to stimulate flow of milk (3).

Osmorhiza longistylis (Torr.) DC. Plant: eye remedy (2); with bark of honey locust for tea to regain strength and flesh (2). Root: tea aids parturition (3); good for sore throat (3); eye lotion (4); tea as stomachic (4).

Ostrich Fern: Matteuccia strutiopteris (L.) Todaro

Ostrya virginiana (Mill.) K. Koch Bark: infusion for flux (4). Bark and inner wood: alterative, antiperiodic, tonic (5).

Ox-eye: Heliopsis helianthoides (L.) Sweet

Pale Coneflower: Echinacea pallida Nutt.

Pale Smartweed: Polygonum lapathifolium L.

Panax quinquefolius L. Root: sore gums (2); pyorrhoea (2); stomach troubles (2); remedy for the menses (2); the best medicine for flux (2); pounded into poultice for earache (4); soak pounded root to make wash for sore eyes (4). Root (whole, dried): aromatic bitter, mild stimulant, stomachic (5).

Parietaria pennsylvanica Muhl. Herb: deobstruent, diuretic, emmenagogue (5).

Parthenocissus quinquefolia (L.) Planch. [= Psedera quinquefolia (L.) Greene] Root: tea for diarrhea (2).

Pasture Rose: Rosa carolina L.

Pellitory: Parietaria pennsylvanica Muhl.

Pennyroyal: Hedeoma pulegioides (L.) Pers.

Penthorum sedoides L. Seeds: cough syrup (2).

Peppercress, Common: Lepidium virginicum L.

Persimmon: Diospyros virginiana L.

Phlox, Downy: Phlox pilosa L.

Phlox, pilosa L. Leaves: tea as wash for eczema (2); tea to cure and purify blood (2).

Phytolacca americana L. Leaves, roots and ripe berries: alterative, emetic, purgative (5).

Pigweed: Amaranthus retroflexus L.

Pimpernel, Yellow: Taenidia integerrima (L.) Drude

Plantago rugelii Dcne. in DC. Leaves: fresh-applied to reduce swellings (1).

Plantain, Common: Plantago rugelii Dcne. in DC.

Plantanus occidentalis L. Bark: tea for colds and as a blood purifier (2); washing pustules of smallpox dries them up (2); tea for lung troubles and hemorrhage (2); eat bark to dispel internal pains (2).

Plum, Wild: Prunus americana Marsh.

Podophyllum peltatum L. Root (rhizome?): cathartic (2); poultice for snake bite (2); tea for dropsy (2). Rootstock: drastic purgative and hydragogue (5).

Poison Ivy: Rhus radicans L.

Pokeweed: Phytolacca americana L.

Polemonium reptans L. Plant: with mayapple root used as a urinary or physic (2).

Polygonatum commutatum (Schultes) Dietr. [= P. biflorum (Walt.) Ell.] Root (rhizome?): burned as smudge to revive consciousness (1, 2); physic (3); tea to treat cough (3). Rhizome and roots: allay irritation of the mucous membranes (5).

Polygonum lapathifolium L. Whole plant: tea for fevers (4).

Pond-lily, Yellow: Nuphar advena (Ait.) Ait.f.

Potato-vine, Wild: Ipomoea pandurata (L.) Meyer

Prickly-ash: Zanthoxylum americanum Mill.

Prunus americana Marsh. Root bark: astringent for mouth canker (2).

Prunus serotina Ehrh. Bark: tea for coughs and colds (3).

Prunus virginiana L. Inner bark: poultice to heal wounds (1); tea for diarrhea (1). Root bark: tea a sedative and for stomach troubles (2); tea a rectal douche for curing the piles (2). Dried berries: tea for diarrhea (1).

Ptelea trifoliata L. White root bark: seasoner and makes other remedies potent (1, 2). Root: poultice for snake bite (2); tea for dropsy (2); lung troubles (2).

Pteridium latiusculum (Desv.) Hieron. ex R. E. Fries [= Pteris aquilina L.] Root (rhizome?): tea for caked breast (1).

Purple rocket: Iodanthus pinnatifidus (Michx.) Steud.

Pussytoes: Antennaria plantaginifolia (L.) Hook.

Quercus alba L. Inner bark: mixed with other species (1); emetic (2); for eczema, sores (2); universal remedy for all sicknesses (2); tonic, astringent (5).

Quercus macrocarpa Michx. Bark and wood: with other species to expel pinworms (2). Bark: astringent (3). Acorns: internal medicine (2).

Quercus rubra L. Bark: heart troubles and bronchial affections (3). Inner bark: astringent to cure flux (4).

Quercus velutina Lam. Bark: crushed and boiled to give watery infusion for sore eyes (1). Inner bark: mixed with other species for treating lung troubles (2).

Ragweed: Ambrosia artemisifolia L.

Ragweed, Giant: Ambrosia trifida L.

Ranunculus abortivus L. Roots: styptic to stop nose bleed (2).

Ranunculus pennsylvanicus L.f. Whole plant: astringent (4).

Ratibida pinnata (Vent.) Barnh. [= Lepachys pinnata (Vent.) T. & G.] Root: toothache (2).

Rattlesnake Grape-fern: Botrychium virginianum (L.) Sw.

Rattlesnake-master: Eryngium yuccifolium Michx.

Red Cedar: Juniperus virginiana L.

Red Mulberry: Morus rubra L.

Red Oak: Quercus rubra L.

Rhus aromatica Ait. Bark: aromatic (5).

Rhus glabra L. Root bark: rubefacient (2); tea as hemostatic (3). Trunk and twig inner bark: in combination with other species as an astringent (3). Leaves: poultices (3). Flowers: steeped for sore eyes (3). Fruits: throat cleanser (3). Leaves, fruits, bark of stem and roots: astringent, gargle, refrigerant (5).

Rhus radicans L. [= R. toxicodendron L.] Root: pounded into poultice to put on swelling to make it open (2).

Rigid Goldenrod: Solidago rigida L.

Rocket, Purple: Iodanthus pinnatifidus (Michx.) Steud.

Rosa carolina L. [= R. humilis Marsh.] Fruit: skins eaten to cure stomach trouble (1).

Rose, Pasture: Rosa carolina L.

Rosinweed: Silphium integrifolium Michx.

Rubus allegheniensis Porter Root: infusion to cure sore eyes (1, 2, 4); poultice; tea for stomach trouble (2); extract for arresting flux (3); astringent (5). Canes: diuretic (3). Bark: astringent (5). Fruit: syrup used as a vehicle for other drugs (5).

Rudbeckia hirta L. Root: tea for colds (4).

Sage, Wood-: Teucrium canadense L.

Sagittaria latifolia Willd. Corms: pulped as a poultice for wounds and sores (4).

Salix nigra Marsh. Bark and buds: antiperiodic, tonic (5).

Sambucus canadensis L. Flowers: dried - tea used as febrifuge (1). Bark of root: tea used in extremely difficult cases of parturition (2). Flowers: mild astringent in eye lotion (5). Inner bark of stem and bark of root: cathartic (5).

Sanguinaria canadensis L. Root (rhizome?): added to other medicines to strengthen their effect (1); fresh juice on maple sugar to cure sore throat (1, 3, 4); tea to bathe burns (2); chewed and the spittle put on burns to relieve pain (2); remedy for the menses (2); stomach trouble (2); good for flux (2). Rootstock: emetic, expectorant, sternutatory (5).

Sanicula gregaria Bickn. Whole plant: burned on hot stones - inhale fumes to stop nose bleed (2).

Sassafras: Sassafras albidum (Nutt.) Nees

Sassafras albidum (Nutt.) Nees Bark of root: remedy for fits (2); interior troubles (2); for the lungs and for fever (2). Bark of root and trunk: aromatic stimulant, flavoring agent (5). Pith of young branches: mucilage as a demulcent (5).

Scouring-rush, Tall: Equisetum hyemale L.

Scutellaria lateriflora L. Leaves and tops: antispasmodic, nervine, tonic (5).

Scutellaria parvula Michx. Plant: treatment of flux (2).

Senna, Wild: Cassia marilandica L.

Sensitive Fern: Onoclea sensibilis L.

Shagbark Hickory: Carya ovata (Mill.) K. Koch

Shellbark Hickory: Carya laciniosa (Michx f.) Loud.

Showy Goldenrod: Solidago speciosa Nutt.

Silene stellata (L.) Ait.f. Root: used to dry up swellings that discharge pus (2).

Silphium integrifolium Michx. Leaves: tea for bladder troubles (2).

Silphium laciniatum L. Root: internal medicine (2); aleviate vomiting of pregnancy (2); reduce profuse menstruation (2); lumbago and other rheumatic back pains (3); stomach trouble and hemorrhage (3).

Skullcap: Scutellaria lateriflora L.

Skullcap: Scutellaria parvula Michx.

Slippery Elm: Ulmus rubra Muhl.

Small-flowered Buttercup: Ranunculus abortivus L.

Smartweed, Pale: Polygonum lapathifolium L.

Smilacina racemosa (L.) Desf. Root (rhizome?): fumes inhaled, from ground up, boiled "root," by person suffering from catarrh (1); smudge for fits or insanity (2); smudge as a reviver (4).

Smooth Sumac: Rhus glabra L.

Snakeroot, Common: Sanicula gregaria Bickn.

Snakeroot, Virginia: Aristolochia serpentaria L.

Snakeroot, White: Eupatorium rugosum Houtt.

Sneezeweed: Helenium autumnale L.

Solanum carolinense L. Ripe berries, rootstock: antispasmodic and sedative (5).

Solidago altissima L. [= S. canadensis L.] Flowers: tea for fevers (4).

Solidago latifolia L. Whole plant: tea for certain fevers (4).

Solidago media (Greene) Bush ex. Friesner [as S. graminifolia (L.) Salisb.] Flowers: infusion for pain in chest (3); infusion to cure fevers (4).

Solidago rigida L. Flowers: lotion to reduce bee sting swelling (2).

Solidago speciosa Nutt. Root: tea heals burns or scalding from steam (2).

Solidago uliginosa Nutt. Root: poultice to bring boil to head (4).

Solidago ulmifolia Muhl. ex. Willd. Plant: reviver of consciousness (2).

Solomon's-seal: Polygonatum commutatum (Schultes) Dietr.

Solomon's-seal, False: Smilacina racemosa (L.) Desf.

Specularia perfoliata (L.) A.DC. Plant: emetic (2).

Spikenard: Aralia racemosa L.

Spotted Horsemint: Monarda punctata L.

Spotted Touch-me-not: Impatiens biflora Walt.

Spurge, Flowering: Euphorbia corollata L.

Squirrel-corn: Dicentra canadensis (Goldie) Walp.

Stachys aspera Michx. [= S. tenuifolia var. aspera (Michx.) Fern.] Leaves: tea for bad cold (2); makes patient vomit (2).

Starry Catchfly: Silene stellata (L.) Ait.f.

Stone-crop, Ditch: Penthorum sedoides L.

Strawberry, Wild: Fragaria virginiana Duch.

Sugar Maple: Acer saccharum Marsh.

Sumac, Fragrant: Rhus aromatica Ait.

Sumac, Smooth: Rhus glabra L.

Sunflower: Helianthus strumosus L.

Swamp Goldenrod: Solidago uliginosa L.

Swamp Milkweed: Asclepias incarnata L.

Sweet Cicely: Osmorhiza longistylis (Torr.) DC.

Sweet Everlasting: Gnaphalium obtusifolium L.

Sweet-scented Bedstraw: Galium triflorum Michx.

Sweetflag: Acorus calamus L.

Sycamore: Platanus occidentalis L.

Taenidia integerrima (L.) Drude in Eng. & Pr. Root: steeped, then chewed for bronchial affections (1).

Tall Anemone: Anemone virginiana L.

Tall Scouring-rush: Equisetum hyemale L.

Tall Tickseed: Coreopsis tripteris L.

Teucrium canadense L. Herb: aromatic, diophoretic, diuretic, emmenagogue, stimulant (5).

Thistle, Field: Cirsium discolor (Muhl.) Spreng.

Tickseed, Tall: Coreopsis tripteris L.

Tilia americana L. Inner bark: poultice to cause boils to open (2). Twigs: tea for lung trouble. Flowers, flowers with leaves: stimulant or sedative (5). Bark: emollient (5).

Toadflax, False: Comandra umbellata (L.) Nutt.

Touch-me-not, Spotted: Impatiens biflora Walt.

Triosteum perfoliatum L. Root: snake bite (2); healing old raw sores (2); used on new-born infant with sore head (2); tea for cleaning the system (2); cathartic, emetic (5).

Typha latifolia L. Fruit fuzz: used as padding on old sores (2). Root (rhizome?): poultice for various inflammations (4).

Ulmus americana L. Root bark: eye lotion for sore eyes (2). Bark: cramps and diarrhea (4).

Ulmus rubra Muhl. [= U. fulva Michx.] Inner bark: tea as physic (1); draw pus from a wound (1,4); internal medicine (2); poultice for old sores (2); sore throat (3); chewed and applied to inflammed eye (4). Root: tea for women so they may deliver easily (2).

Umbrella-wort: Mirabilis nyctaginea (Michx.) MacM.

Urtica gracilis Ait. Leaves, tops and seeds: antihemorrhagic, catharrhal affections, counter-irritant, diuretic (5).

Uvularia grandiflora Sm. Plant: reduce swellings (1). Root: infusion for backache (4); boiled down with lard to make a salve to massage sore muscle and tendons (4).

Venus' Looking-glass: Specularia perfoliata (L.) A.DC.

Verbena hastata L. Root: tea to clear up cloudy urine (1); remedy for fits (2); remedy for eczema (2). Herb: emetic, expectorant, tonic (5).

Verbena urticifolia L. Root: tea to cure profuse menstruation (2).

Veronicastrum virginicum (L.) Farw. [= Veronica virginica L.] Root: physic (1); fits (2); constipation (2); dissolve gravel in kidneys (2); tea for ague of long standing (2). Rhizome and roots: cholagogue, emetic, laxative (5).

Vervain, Blue: Verbena hastata L.

Vervain, White: Verbena urticifolia L.

Viburnum lentago L. Inner bark: tea as diuretic (3).

Viburnum prunifolium L. Bark of root and stem: antispasmodic, astringent, nervine, tonic, uterine sedative (5).

Viola pedata L. Leaves and rhizome: cathartic, emetic, expectorant (5).

Violet, Birdfoot-: Viola pedata L.

Virginia-creeper: Parthenocissus quinquefolia (L.) Planch.

Virginia Snakeroot: Aristolochia serpentaria L.

Virginia Waterleaf: Hydrophyllum virginianum L.

Vitis vulpina L. Twigs: tea to clear up afterbirth and enable it to pass easily (3).

Wafer-ash: Ptelea trifoliata L.

Wahoo: Euonymus atropurpureus Jacq.

Walnut, Black: Juglans nigra L.

Water-Hemlock: Cicuta maculata L.

Water-Horehound: Lycopus americanus Muhl. ex Bart.

Water-Lily, Fragrant: Nymphaea odorata L.

Waterleaf, Virginia: Hydrophyllum virginianum L.

White Ash: Fraxinus americana L.

White Baneberry: Actea alba (L.) Mill.

White Indigo: Baptisia leucantha T. & G.

White Oak: Quercus alba L.

White Snakeroot: Eupatorium rugosum Houtt.

White Vervain: Verbena urticifolia L.

Whitetop: Erigeron annus (L.) Pers.

Willow, Black: Salix nigra Marsh.

Wood Nettle: Laportea canadensis (L.) Gaud.

Wood-sage: Teucrium canadense L.

Yam: Dioscorea villosa L.

Yarrow: Achillea millefolium L.

Yellow Pimpernel: Taenidia integerrima (L.) Drude

Yellow Pond-lily: Nuphar advena (Ait.) Ait.f.

Yellowish Gentian: Gentiana alba Muhl.

Zanthoxylum americanum Mill. Root bark: poultices (1). Bark: expectorant (2); used with other species when bladder contents are thick (2). Inner bark: powdered for toothache (2). Fruit: expectorant (2); pile medicine (2); interior troubles for lungs and fevers (2); tea to spray on chest or throat for bronchial diseases (1, 3). Ripe fruits and bark of stems: diaphoretic, simple bitter, stimulant (5).

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THE GENUS POLYGONATUM (SOLOMON'S SEAL) IN SOUTHERN ILLINOIS

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ABSTRACT. - The taxonomic delimitation of the Polygonatum biflorum -- P. canaliculatum complex has been a source of controversy for many years. In the present study several graphical techniques of analysis, including scatter-diagrams, hybrid indices, and radiate indicators, were used to examine the range of morphological variation in specimens of P. biflorum and P. canaliculatum collected from southern Illinois and other localities. The results show that P. biflorum can be distinguished from P. canaliculatum on the basis of its anther length, number of veins per leaf, number of flower pedicels per peduncle, and type of leaf margin, but not by any single characteristic alone. The disposition of the species "P. commutatum" is also dealt with.

The classification of the species of Polygonatum (Lily Family) native to southern Illinois has long posed a problem to the taxonomist. According to Fernald (1950) and Gleason (1952), only two species, P. biflorum and P. canaliculatum, occur in Illinois. Jones (1963), on the other hand, lists P. commutatum and P. biflorum as occurring in our area, and synonymizes P. canaliculatum with the latter species. Polygonatum commutatum, however, has been placed in synonymy with P. canaliculatum by Fernald (1950), and under P. canaliculatum (in part), and P. biflorum (in part) by Gleason (1952). Ownbey's (1944) treatment of Polygonatum, the only recent monograph of the genus, synonymizes the name P. canaliculatum with P. biflorum, and transfers all specimens previously annotated as P. canaliculatum to the species P. commutatum. Ownbey was unable to adequately separate P. biflorum and P. canaliculatum solely by their morphology, but she could distinguish two distinct populations which differed by their chromosome number.

While the nomenclatural problem will be dealt with in greater detail in a forthcoming paper, the present authors have chosen to follow Gleason's (1952) and Fernald's (1950) classification of the species of this group for reasons that will become more apparent later. The primary objective of the present work is to ascertain the limits of morphological variation within and between the taxa present in southern Illinois, and to show that these may be delimited solely on the basis of morphological criteria.

HISTORICAL REVIEW OF THE GENUS

Linnaeus (1753) listed the following three species of Polygonatum under the genus Convallaria: C. verticillata, C. Polygonatum, and C. multiflora. In 1785, Allioni transferred these to the genus Polygonatum, thus changing the name of the type species (Convallaria Polygonatum L.) to Polygonatum officinale All. (Ownbey, 1944).

Convallaria biflora, the first American species mentioned in the literature (Walter, 1788), was redescribed by Elliott (1821-1824) as Polygonatum biflorum. His brief diagnosis follows:

> Caule tereti, leavi, foliis alternis, sessilibus, elliptico-lanceolatis, trinervibus; pedunculis axillaribus, solitariis, bifloris.
>
> [Stem terete, smooth; leaves alternate, sessile, elliptic-lanceolate, 3-nerved; peduncles axillary, solitary, 2-flowered.]

In 1806, Willdenow described Convallaria pubescens and C. canaliculata Muhl. In 1814, Pursh transferred these two species to the genus Polygonatum. However, his technically poor diagnosis of the key characters of P. canaliculatum has contributed much to the difficulties encountered by taxonomists dealing with this species.

> Polygonatum canaliculatum: Caule canaliculato, foliis alternis amplexicaulibus oblongis margine pubescentibus pedunculis axillaribus bifloris.
>
> [Stem with longitudinal grooves, alternate stem-clasping oblong leaves with a pubescent margin, 2-flowered axillary peduncle.]
>
> Polygonatum pubescens: Caule teretiusculo dulco exarato, foliis alternis amplexicaulibus ovatis subtus pubescentibus, pedunculis axillaribus subbiflorus.
>
> [Cylindric stem with elevated grooves, alternate stem-clasping ovate leaves pubescent underneath, under 2-flowered axillary peduncle.]

Convallaria commutata, added to the North American flora by Schultes (1830), was transferred to Polygonatum commutatum by Dietrich in 1835, who described it as being distinguished by "the angular stem and by the pointed leaves." Dietrich (1835) also described P. giganteum from North America.

Salomonia cobrensis, the New Mexican species described by Wooten and Standley (1913), which, however, does not occur in Illinois, was recognized as Polygonatum cobrense in Gates's (1917) revision of the genus in North America. A number of other North American species, described from areas

outside Illinois, have appeared in the literature: P. latifolium (Pursh, 1814); P. multiflorum β. Americanum (Hooker, 1839); and P. cuneatum, P. virginicum, and P. boreale (Green, 1906).

Ownbey's (1944) monograph of Polygonatum in North America recognizes four species and three varieties: P. pubescens, P. cobrense, P. biflorum (P. biflorum vars. melleum, hebetifolium, and necopinum), and P. commutatum.

The key to the species of Polygonatum in Mohlenbrock's (1970) Flowering Plants -- Lilies to Orchids essentially follows Ownbey's taxonomic treatment of the genus. Jones's 1950 Flora of Illinois treats only two species, P. pubescens and P. commutatum. The latest treatments of these species for the Midwest are by Fernald (1950), Gleason (1952), and Jones (1963). Fernald's 8th edition of Gray's Manual of Botany lists four species of Polygonatum: P. pubescens, P. latifolium (introduced from Europe), P. biflorum, and P. canaliculatum. Fernald indicates that P. commutatum (R. & S.) Dietr. is synonymous with P. canaliculatum. Gleason, on the other hand, recognizes four species of Polygonatum: P. pubescens, P. canaliculatum (P. commutatum, in part; P. giganteum), P. biflorum (P. commutatum, in part), and P. melleum. In the 3rd edition of the Flora of Illinois, Jones lists only three species: P. pubescens, P. biflorum [P. canaliculatum (Muhl.) Pursh], and P. commutatum [P. giganteum Dietr.; P. canaliculatum sensu Fern.]. No other treatments are available.

MORPHOLOGY

Rhizome. All species of the genus are characterized by the presence of knotted branching rhizomes. Fernald (1950) states that the rhizome is superficial in Polygonatum pubescens and buried in P. biflorum and P. canaliculatum.

Stem. In all North American species the stem is glabrous. It may be terete, angular or channeled, but this character is not of much value in species delimitation based on herbarium material. In P. pubescens the stem is 2-11 dm tall (2-11 dm in Fernald, 1950; 5-9 dm in Gleason, 1952; and 3-9 dm in Ownbey, 1944); P. biflorum's stem is 2-9 dm tall (2-9 dm in Fernald, 1950; 4-6 dm in Gleason, 1952; up to 6 dm in Ownbey, 1944). All authors agree that P. canaliculatum is the largest plant having a stem 5-20 dm tall (6-20 dm in Fernald, 1950; 6-12 dm in Gleason, 1952; 5-20 dm in Ownbey, 1944).

Leaves. In all the North American species the leaves are alternate, and vary considerably in size and shape within each species. The leaves of P. pubescens are pubescent beneath along the veins, a character which readily distinguishes this species from P. biflorum and P. canaliculatum, which both have glabrous leaves. Ownbey (1944) states that the leaves of P. pubescens have a "fine pubescence on the minor nerves beneath." The few out-of-state specimens compared in this study were also pubescent along the major nerves, although the degree of pubescence varied from specimen to specimen. The shape of the leaves in each species is highly variable, although it is generally agreed (Fernald, 1950; Gleason, 1952; Ownbey, 1944) that the leaves of P. pubescens are elliptic-lanceolate to broadly oval, those of P. biflorum are elliptic-lanceolate (to broadly ovate according to Fernald), and those of P. canaliculatum are lance-elliptic to broadly ovate. Leaf size varies considably within each species, and the reported limits of variation differ with the various authors. It is obvious that there is so much overlap among the three species in leaf measurements, that these character states are of little taxo-

nomic worth when used as absolute values. However, if a leaf width/length ratio is calculated for each specimen, it can be used in conjunction with other characters to delimit the three species (see Fig. 2A). In P. pubescens the leaves are often, but not always, shortly petiolate; in P. biflorum and P. canaliculatum they are sessile or amplexicaulous. The state of the leaf margin provides a relatively good character for distinguishing P. canaliculatum from the other two species. In P. pubescens and P. biflorum the leaf margins are smooth, while those of P. canaliculatum are typically undulate or wavy. The nervation of the leaves presents a nearly constant character but one which is somewhat difficult to use. The leaves of P. pubescens, according to all authors, have 3-9 prominent nerves with typically only the midrib extending to the apex of the leaf; in P. biflorum there are 1-5 (rarely 9, and most typically 7) prominent nerves with only the midrib extending to the apex of the leaf. In P. canaliculatum there are many major nerves (7-22 or more) extending the length of the leaf. There is some discrepancy among the values reported for this character by the various authors, particularly those values reported by Fernald, who based his figures on all veins of the leaf, both major and minor.

Inflorescence. In P. pubescens and P. biflorum each axillary peduncle bears 1 or 2, or rarely 3, flowers. In P. canaliculatum there is great variation in the number of flowers per peduncle: 2-10 according to Fernald (1950); 1-15 according to Gleason (1952) and Ownbey (1944); and 2-9 in the specimens housed in the SIU herbarium. Pedicel/peduncle length ratios (see Fig. 2C) for all three species overlap too much to be of significant taxonomic value by themselves.

Perianth. According to Ownbey (1944) and other authors the size and color of the perianth are of some taxonomic value. However, measurements of perianth size overlapped so much among the three species that this character state was not used. Flower shape and color may be useful in living material, but not for dried specimens.

Stamens. The six stamens, inserted on the perianth tube in all species, have more or less papillose filaments and introrse anthers. Prior to this paper the anther length has not been used as a distinguishing character, however, in our opinion, it is an excellent character which does not vary greatly within each species. In P. pubescens anther length measures 2.2-2.3 mm, while in P. biflorum and P. canaliculatum it is 2.1-3.1 (rarely more than 3.1) mm and 3.9-4.8 (rarely less than 3.9) mm, respectively.

Pistil. The sessile to subsessile ovary is oblong to globose in shape, and is trilocular, having several ovules per cell. The style is filiform and shorter than the perianth (Ownbey, 1944). The style length, although more variable than the anther length, is also of some taxonomic value in separating the three species. In P. pubescens style length measures 3.8-4.8 mm, while in P. biflorum it measures 1.6-8.0 mm (rarely 10.0 mm), and in P. canaliculatum (rarely 3.0) 5.8-10.8 mm. All authors agree the stigma is capitate or obtuse, and obscurely three-lobed.

Fruit and seeds. According to all authors the fruit is a dark blue or black, globose, pulpy, several-seeded berry. The berries of P. canaliculatum are usually larger and have more seeds than those of the other two species.

GENERIC RELATIONSHIPS

Polygonatum is superficially most similar to the liliaceous genera Disporum, Streptopus, Convallaria, and Smilacina. According to Fernald (1950), the genus Disporum, which has two species, D. lanuginosum and D. maculatum, is distinguished from Polygonatum by several floral and vegetative characteristics. These include: bell-shaped flowers with perianth segments separate to the base; solitary or small umbel-like clusters of two or three flowers terminating the branches; stem dichotomously forked above the rhizome; several, sessile, reticulately veined leaves; fruit yellow or red; and anthers which are extrorse.

Streptopus, commonly called "twisted stalk," has two species, S. amplexifolius and S. roseus, both of which are distinguished from Polygonatum by the following: campanulate to rotate perianth with segments separate to the base, and recurved or spreading at the tips; fruit red; leaves cordate at the base (S. amplexifolius) or if sessile, leaves ciliate (S. roseus); and anthers which are extrorse (Fernald, 1950; Gleason, 1952).

Convallaria, the genus which included many of the earlier described species of Polygonatum, differs from the latter species by its campanulate perianth with six short, recurved lobes; stout style; triangular stigma; red berry; acaulescence; and angled scape bearing a one-sided, many-flowered raceme (Fernald, 1950).

False Solomon's-Seal, Smilacina, although vegetatively similar to Polygonatum, can be distinguished from the latter by its floral characteristics. These include: sepals and petals which are distinct rather than united, and inflorescences which are terminal and not one-sided (Fernald, 1950).

DISTRIBUTION

Polygonatum, a genus of about 50 species (Willis, 1966), is widely distributed in north temperate regions, with many more species occurring in Europe and in temperate Asia than in North America. There are discrepancies in the precise limits of distribution of two of the three species in North America as reported by Fernald (1950) and Gleason (1952). According to both Fernald and Gleason, P. pubescens occurs from southern Quebec, down along the Atlantic coast to South Carolina, west to Iowa, and north to southern Manitoba.

The range of P. biflorum, according to Fernald, extends from southern Ontario to Florida, west to Texas, and north to Nebraska, whereas Gleason restricts its range to east of the Mississippi River.

According to Fernald, P. canaliculatum ranges from southern Manitoba, down along the Atlantic coast to South Carolina, and west to Oklahoma. Gleason extends its southern boundary range to Georgia and Texas.

The Illinois distribution for each species is given in Figure 1. Open circles represent specimens of Polygonatum housed in the SIU herbarium, filled circles other sources (Pepoon, 1927; Jones, 1942; Ownbey, 1944; Jones and Fuller, 1955; Winterringer and Evers, 1960; Mohlenbrock et al., 1962, 1966; Ozment, 1967). Filled triangles represent specimens for which exact locality data is unknown.

According to Fernald (1950), all three species are found in similar habitats. Polygonatum pubescens grows in woods, along wooded bluffs, and about boulders in woods; P. biflorum occurs in dry to moist, sandy, loamy or rocky woods and thickets; and P. canaliculatum is found in rich woods, alluvial thickets, riversilts, etc. Illinois plants of P. biflorum and P. canaliculatum occur in essentially the same type of habitat, that is, moist woods, and wooded and dry bluffs. However, according to Ownbey (1944), P. canaliculatum shows greater tendency to invade open places, roadsides, fence rows, and alluvial soils than P. biflorum.

Since the ranges of the three species are sympatric and their habitats are quite similar, they must be isolated in nature by some other mechanism, such as different flowering times, different insect pollinators, etc. A comparison of the flowering times of Illinois specimens of P. biflorum and P. canaliculatum (see Fig. 1) drawn from the same climatic tension zone (Ugent and Anderson, 1969) would appear to show little difference in the flowering dates. However, if a normal curve is extrapolated for each species, it is apparent that the peak flowering times are probably separated from each other by at least 2-3 weeks.

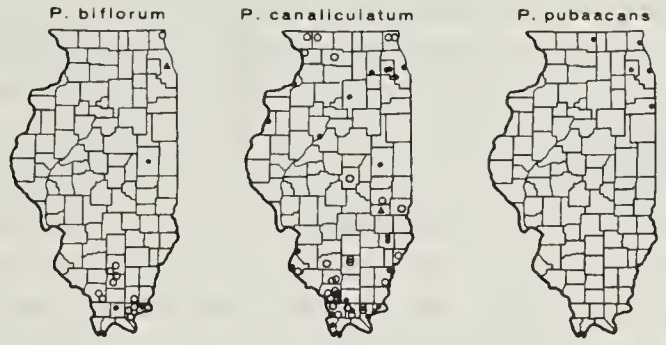
ANALYSIS OF VARIATION

Morphological variation in Polygonatum is best illustrated by graphical methods of analysis. In the present study the following techniques were used: (1) pictorialized scatter-diagrams, (2) hybrid indices, and (3) radiate indicators.

(1) Pictorialized Scatter-Diagrams. Pictorialized scatter-diagrams, a technique developed by Edgar Anderson (1949), were utilized to illustrate variation within and between the species of Polygonatum and to resolve the P. commutatum "problem."

The first and most important task in the preparation of a scatter-diagram is to obtain a variety of character measurements, and then to select for plotting those variables which most clearly isolate the species involved. The following characters were selected for evaluation:

1. Leaf width/length. The fourth leaf above the lowermost flower of the inflorescence was selected for measurement. The width was measured at the exact midpoint of the leaf.
2. Number of veins/leaf (fourth leaf above the lowermost flower of the inflorescence). Only those veins reaching or almost reaching the leaf apex were scored.
3. Leaf margin. The leaf margin was scored as follows: 0 = smooth and 1 = undulate.
4. Leaf pubescence. Scored as follows: 0 = underside of leaf glabrous and 1 = underside of leaf pubescent.
5. Maximum number of flower pedicels/peduncle.
6. Pedicel length/total peduncle length.
7. Anther length. It was felt that the absolute size of a reproductive structure could be used with confidence, since floral structures are generally considered to be genetically and environmentally conservative (Davis and Heywood, 1963).



Data	No. of Indiv.	Flowars
Apr. 15-30	4	2
May 1-15	3	3
May 16-31	1	6

o Harbarium spacimana
● Spacimens from othar aourcaa
▲ Exact locality unknown

FIG. 1

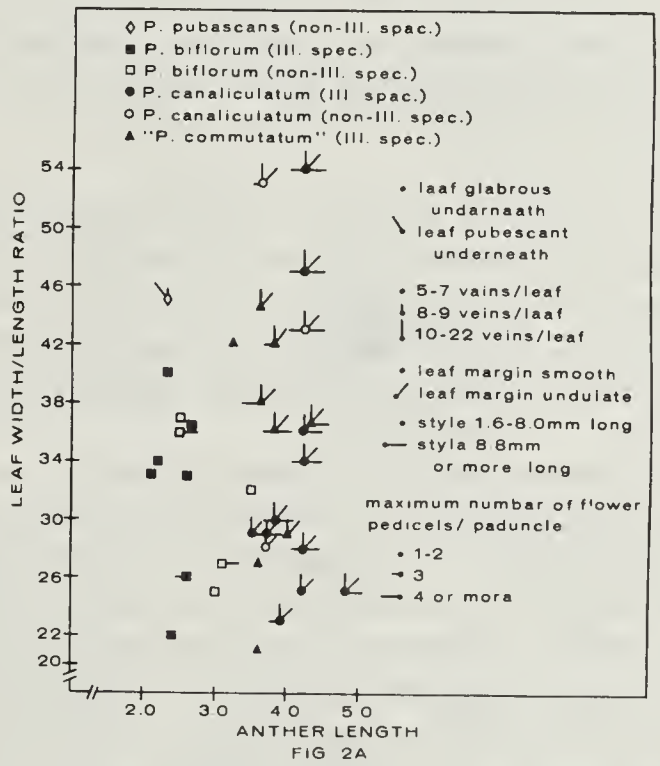


FIG 2A

Figure 1. Geographical distribution of the species of Polygonatum native to Illinois (see text for further explanation).

Figure 2. Morphological variability in Illinois species of Polygonatum.

8. Style length. Although more variable than anther length, this character also proved to be of value.

The shape of the leaf base and position of the stamen on the perianth tube proved to be too variable in preserved specimens, therefore, these characters were discarded.

Four different scatter-diagrams were made using different character combinations on the axes. Additional characters were added as glyphs (or "cat whiskers"). If anther length versus leaf width/length is plotted on a scatter-diagram (Fig. 2A), Polygonatum biflorum and P. pubescens are readily separated from P. canaliculatum. Polygonatum pubescens is distinguishable from P. biflorum by the pubescence on the underside of its leaves. This scatter-diagram also amply illustrates the great amount of variation in the P. canaliculatum population, a topic which will be discussed in some detail later. Some of our P. commutatum specimens clearly fall within the variability limits of P. biflorum, while others fall within the limits of P. canaliculatum.

By plotting the maximum number of flower pedicels/peduncle against the anther length (Fig. 2B), a distinct separation of the three species is also obtained. This diagram illustrates that specimens of P. biflorum and P. pubescens have a much lower maximum number of pedicels/peduncle (1-3, but typically 2), that individuals of P. canaliculatum which vary from 2-5. Our specimens of P. commutatum again fall into two discrete groups.

When anther length is plotted against the pedicel length/total peduncle length (Fig. 2C), although the latter is quite variable within all the species involved, P. canaliculatum and P. biflorum are still readily separable. Within the "species" P. commutatum we again find that one group of specimens is similar to P. biflorum, while the other is like P. canaliculatum.

Since many of the specimens did not have flowers, a fourth diagram (Fig. 2D) was made plotting maximum number of veins/leaf versus leaf width/length. A separation of the three species is illustrated. Polygonatum biflorum is consistent in its possession of 7 veins/leaf, while P. pubescens, although similar to P. biflorum in many respects, is easily separated from the latter by its pubescent leaves. It is apparent that P. canaliculatum represents a much more variable species than the other two, e.g., in the maximum number of veins/leaf and the maximum number of flower pedicels/peduncle. The large number of P. commutatum specimens scored on this diagram clearly shows that this "species" is composed of entities like P. biflorum and other like P. canaliculatum.

(2) Hybrid Index. The calculation of hybrid indices, another morphological technique of analysis developed by Edgar Anderson (1949), was employed both to reflect the total amount of variation within each species and to attempt to further resolve the P. commutatum problem. Index values were calculated by scoring each character in three grades: 0 for characters like P. biflorum, 1 for intermediate characters, and 2 for characters similar to P. canaliculatum. The same characters used in the scatter-diagrams were used in calculating the hybrid index. An index value was calculated for each specimen, and these values were used in combination with scatter-diagrams. In order to indicate what characters were varying within the index, the characters were

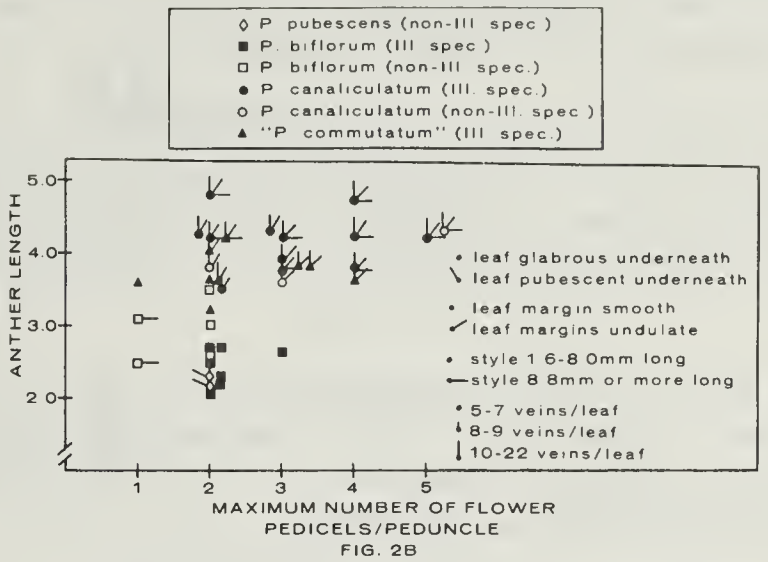


FIG. 2B

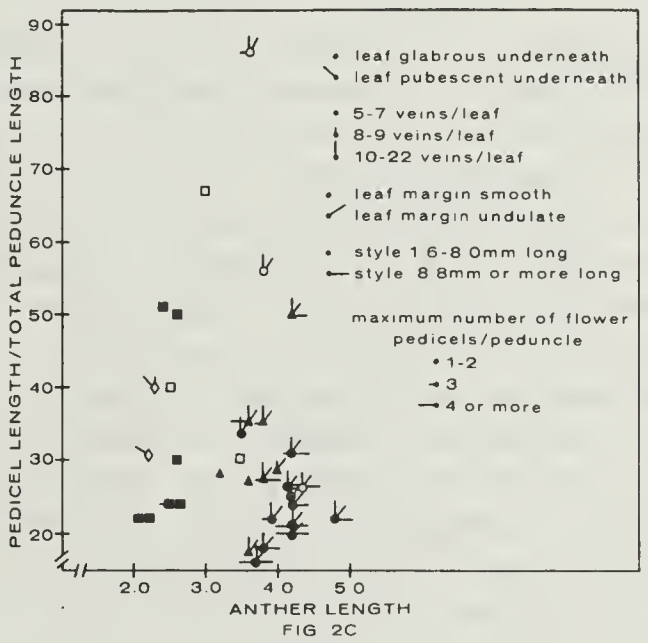


FIG 2C

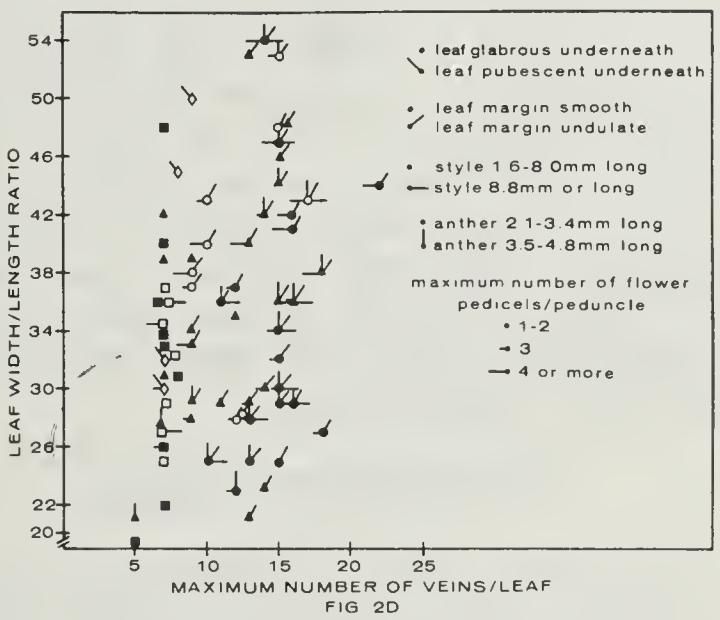


FIG 2D

Figure 2 (continued). Morphological variability in Illinois species of Polygonatum.

added to the diagrams as glyphs. A scatter-diagram (Fig. 3A) plotting a leaf index number (based on the number of veins/leaf and the type of leaf margin) against the maximum number of flower pedicels/peduncle clearly indicates that P. biflorum and P. canaliculatum represent valid taxa. Specimens in our herbarium identified as P. commutatum, on the other hand, either fall within the limits of P. biflorum or P. canaliculatum.

In Figure 3B, anther length is plotted against a composite index number composed of summed indices for all characters except anther length. This diagram again clearly shows P. biflorum and P. canaliculatum as distinct species, and our P. commutatum specimens as a mixture of specimens of both species.

By plotting a floral index (based on the anther length and the style length) against a leaf index (Fig. 3C), the results obtained are similar to those of the other two scatter-diagrams, except the separation between P. biflorum and P. canaliculatum is greater.

(3) Radiate Indicators. Two types of polygonal graphs were used. First, to study variation within each species, the numerical values of each individual specimen's characters were plotted on a single graph. And secondly, to delimit P. biflorum, P. canaliculatum, and P. commutatum, the maximum, minimum, and averages of their respective characters were plotted on separate graphs. Five characters were used: leaf width/length, maximum number of veins/leaf, maximum number of flower pedicels/peduncle, anther length and style length. The characters, which were recorded by a variety of methods, were graphed as percentages of the maximum value obtained for each character. Figure 4, A and B, in which the mean, minimum and maximum values of each character were plotted, illustrates again the clear separation between P. biflorum and P. canaliculatum. The graph of P. commutatum (Fig. 4C) reveals minimum values like those of P. biflorum, maximum values very similar to those of P. canaliculatum, and mean values almost half-way between the latter two species. This graph adds more evidence to the supposition that P. commutatum specimens at the SIU herbarium were really a mixture of mislabelled P. biflorum and P. canaliculatum specimens. Figure 4D, showing the range of variability of each character analyzed in P. biflorum, illustrates that the leaf margin, maximum number of veins/leaf, maximum number of flower pedicels/peduncle, and the anther length are the most stable characters in this species. The polygonal graph of variability in P. canaliculatum (Fig. 4E), on the other hand, illustrates that all except the leaf margin, show a greater range of variability than in P. biflorum. Our specimens of P. commutatum (Fig. 4F) again fall within the variability limits of P. biflorum or P. canaliculatum.

DISCUSSION AND SUMMARY

The application of graphical techniques of analyses, such as pictorialized scatter-diagrams, hybrid indices, and polygonal graphs, suggests the following conclusions about the species studied:

1. Polygonatum pubescens is similar to P. biflorum in most characters studied, except in anther length and pubescence on the lower leaf surface.
2. Polygonatum biflorum seems to be a genetically stable species.

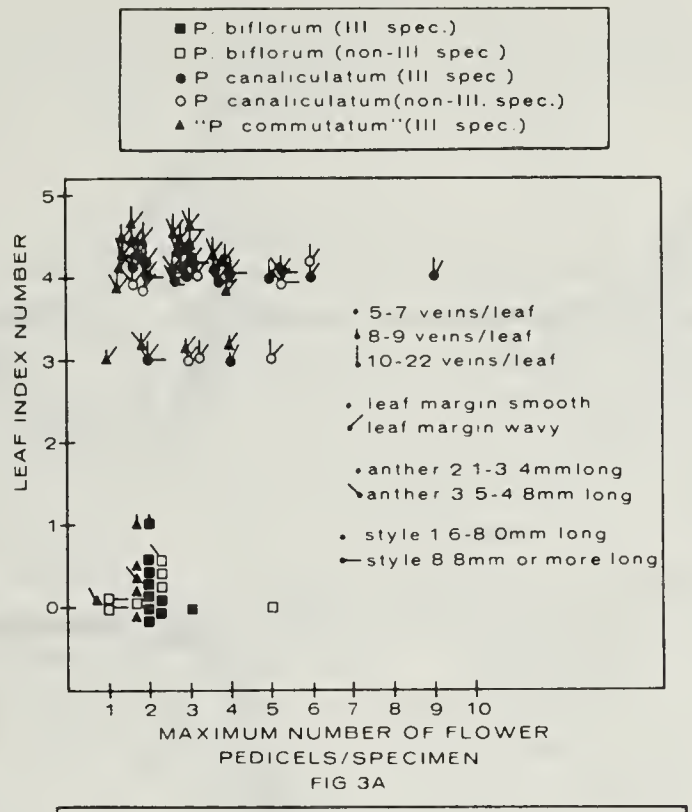


FIG 3A

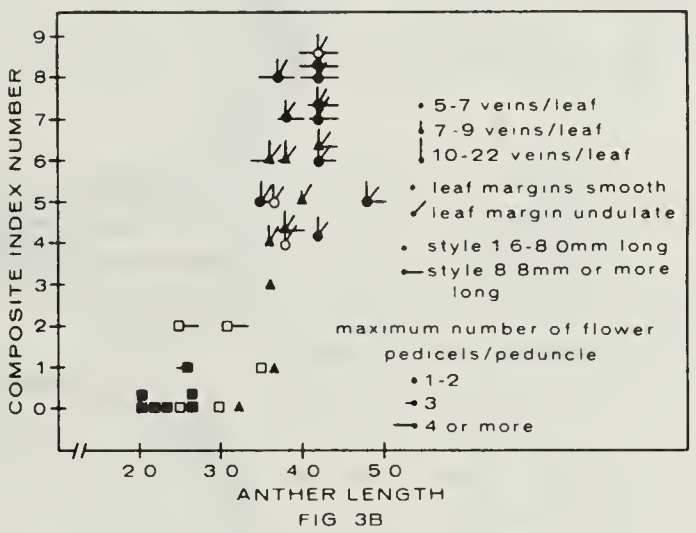


FIG 3B

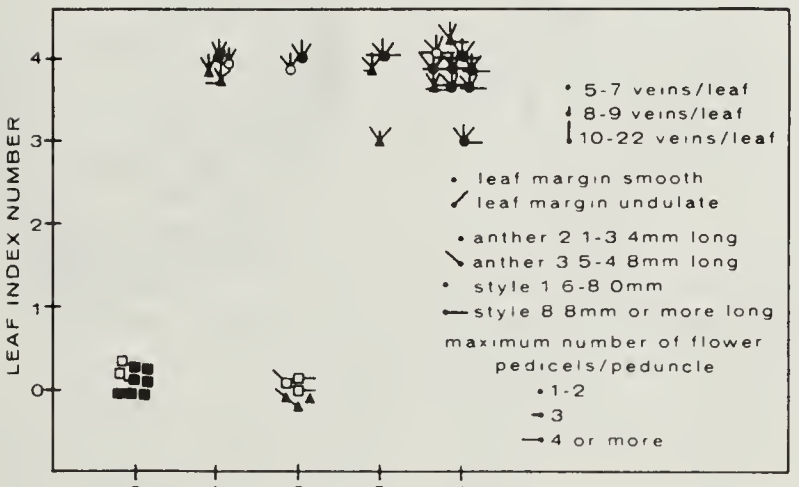
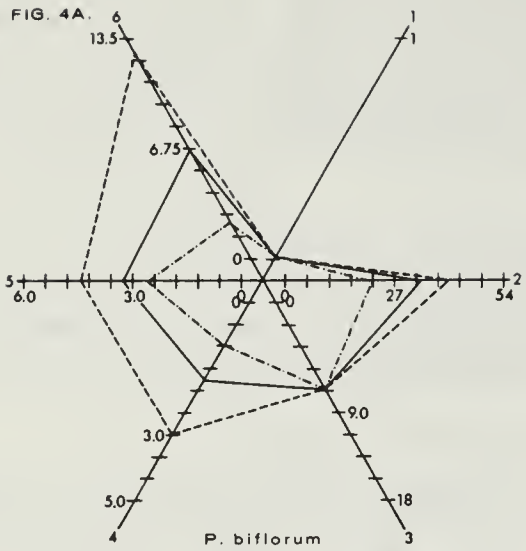
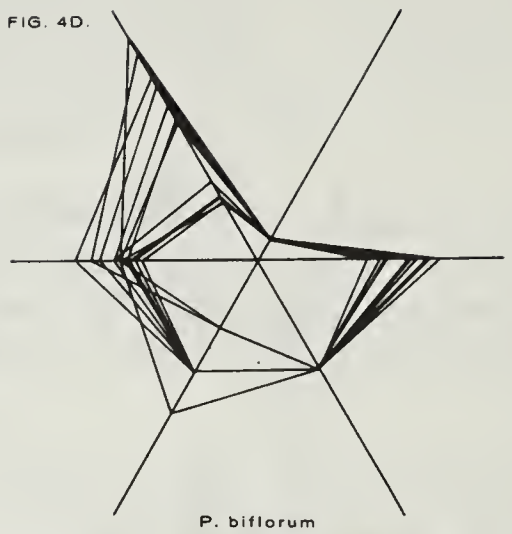
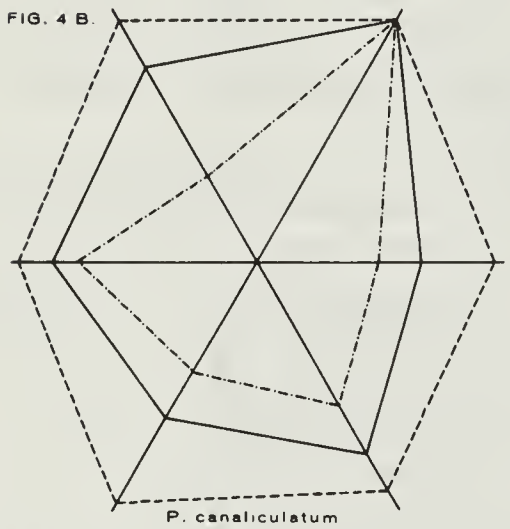


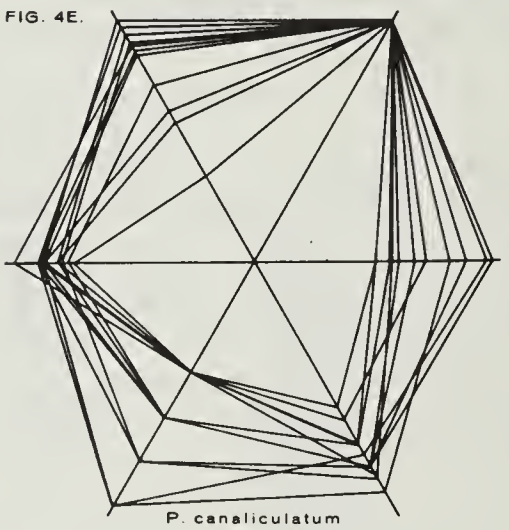
FIG 3C

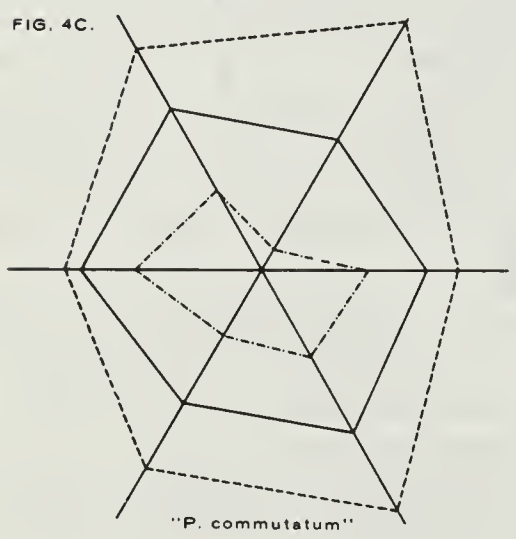
Figure 3. Scatter-diagrams employing hybrid indices based upon leaf characteristics, floral characteristics, and/or leaf and floral characteristics.











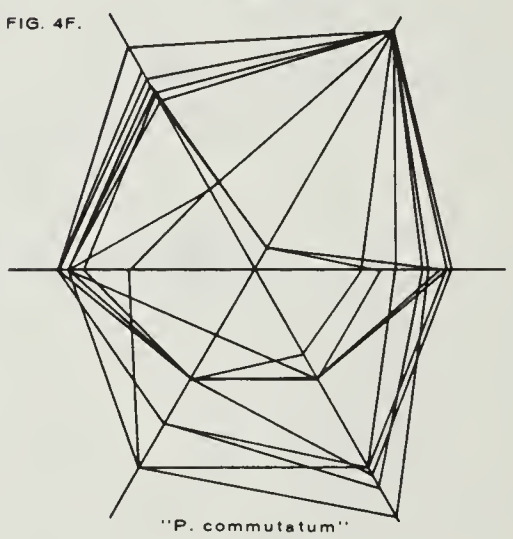


Figure 4. Polygonal graphs. In all diagrams arm 1 equals the type of leaf margin; arm 2, leaf width/length; arm 3, maximum number of veins/leaf; arm 4, maximum number of flower pedicels/peduncle; arm 5, anther length in mm; arm 6, style length in mm. Solid lines on graphs A, B, and C denote the mean value of each character; broken lines, the maximum value; and dots-and-dashes, the minimum value. Each solid line on graphs D-F represents the character values of individual specimens.

3. Polygonatum canaliculatum shows a great amount of variability for almost all characters examined. It is distinct morphologically from P. biflorum in every character investigated, and, would therefore appear to be a valid species.

The P. commutatum-canaliculatum problem is not a simple matter to resolve because it is tied up in a nomenclatural "Gordian knot." Fernald (1950) indicates that P. commutatum is synonymous with P. canaliculatum, whereas Gleason (1952) states that P. commutatum is partly synonymous with P. biflorum and partly with P. canaliculatum. Ownbey (1944), on the other hand, is convinced that P. canaliculatum should be put in synonymy with P. biflorum. Thus, according to Ownbey, all specimens identified as P. canaliculatum should be reannotated as P. commutatum. In our opinion, since Ownbey did not examine the type specimens of either P. canaliculatum or P. commutatum, her justification for synonymizing P. canaliculatum with P. biflorum on the basis of the original description alone is inadequate. Until the type specimens of P. canaliculatum and P. commutatum can be examined and compared with other herbarium specimens, it seems logical to retain the older of the two species names, P. canaliculatum. We maintain this view because the original descriptions of all the species involved are technically poor and, therefore, should not be used as the sole basis for synonymy.

The variability of P. canaliculatum as compared to the relative constancy of P. biflorum has been noted repeatedly throughout this study. Cytological studies of the North American species of Polygonatum have been conducted by various researchers (Eigsti, 1942; Ownbey, 1944; Therman, 1950, 1956; Kawano and Iltis, 1963). While Therman (1956) has shown that a polyploid series from diploid to hexaploid exists in P. canaliculatum, which, if true, would perhaps explain the variability observed in this species, at least in part, the actual taxonomic identity of the species used in this investigation, as pointed out by Kawano and Iltis (1963), is open to question. All plants cytologically examined by Therman were said to be first identified by Ownbey on the basis of their morphology. Yet, in her monograph of the genus Polygonatum, Ownbey (1944) clearly states that P. biflorum and P. canaliculatum (= P. commutatum sensu Ownbey) cannot be separated on the basis of their morphology alone, as is evidenced by the fact her key to the species relies primarily on the chromosome number. According to Kawano and Iltis (1963) little may be done with this problem until the present confused situation is resolved. We, therefore, feel that until cytological work can be done on morphologically authenticated specimens, little reliance can be placed on the chromosome number of the species as reported in the literature. Nevertheless, cytological work does indicate that a polyploid series exists within the genus Polygonatum. Many specimens of P. canaliculatum, for example, exhibit an enhancement of character states typical of the greater vigor which often accompanies higher degrees of polyploidy. These include: a stouter stem; greater number of leaves, flowers, and fruits; larger leaves, flowers, and fruits; broader, thicker many-nerved leaves; and larger anthers.

While it is not known for certain whether or not our smaller plants of P. canaliculatum are diploid, they share certain characteristics in common with the larger plants, and both are readily distinguishable from P. biflorum on the basis of morphology. Ownbey (1944), whose classification of this group relies primarily upon cytological evidence, may be wrong in assuming

all specimens of P. biflorum are diploid and those of P. canaliculatum (= P. commutatum sensu Ownbey) are tetraploid. From a floristic point of view it is not feasible in any event to construct keys based primarily upon chromosome numbers, which, of course, may not be obtained from dried herbarium specimens in the first place. Our study does show, however, that P. biflorum and P. canaliculatum can be separated on the basis of morphology alone.

SYSTEMATIC TREATMENT

Key to the Species

A. Anther length 2.1-3.1 mm (rarely larger) at anthesis; 1-9 veins/leaf leaf margin smooth; 1-2 (rarely 3) flower pedicels/peduncle

1. Leaves pubescent beneath; 3-9 veins/leaf ..... P. pubescens
1. Leaves glabrous beneath; 1-7 (rarely 9, typically 7) veins/leaf ..... P. biflorum

A. Anther length 3.9-4.8 mm (rarely smaller) at anthesis; 7-22 or more veins/leaf; leaf margin undulate; 2-5 flower pedicels/peduncle, typically 3 or more ..... P. canaliculatum

1. Polygonatum pubescens (Willd.) Pursh, Fl. Am. Sept. 1: 234, 1814.

Perennial herb, usually 2-6, but occasionally as much as 9 dm high; rhizome slender, not buried in the soil; stem slender, glabrous, erect or slightly arched at top; leaves alternate, elliptic-lanceolate to elliptic or broadly ovate, narrowed at the base to a short petiole or occasionally sessile, 3.5 to 15 cm long, 1.0 to 7.5 cm broad, glabrous above, pubescent on minor nerves and along major veins beneath, 3 to 9 (typically 7 or 8) prominent nerves running to or almost to the leaf apex; cauline bract subulate, papery, caducous; peduncles axillary, solitary, slender, glabrous, strongly and sharply deflexed, usually 2 (occasionally 1-5)-flowered; pedicels slender, glabrous; filaments densely papillose, inserted near top of perianth tube; anthers 2.2-2.3 mm long; style variable from 3.8-4.8 mm in length; berry dark blue, usually between 7 and 10 mm in diameter.

Representative Specimens: MASSACHUSETTS: HAMPSHIRE CO. Amherst, 17 May 1896, Shepardson 2. MICHIGAN: ST. CLAIR CO. Near Sanilac Co. line, near Jeddo, moist woods, 30 June 1937, Anderson and Peck, s.n. MINNESOTA: STEARNS CO. St. Joseph, May 1964, Sister Remberta, s.n. NORTH CAROLINA: WATAUGA CO. 3.5 mi se of US 421 on Junalaska Road, e slope of Rich Mtn., roadcut through deciduous forest, 9 July 1967, Bozeman, Radford & Culwell 10698. WISCONSIN: DANE CO. 22 May 1957, Ugent, s.n.

2. Polygonatum biflorum (Walt.) Elliott, Sketch Bot. S.C. & Ga. 1: 393, 1817.

Perennial herb 2-9 dm high; rhizome slender, buried in the soil; stem slender, glabrous, erect or arching; leaves alternate, sessile or amplexicaulous , elliptic-lanceolate or ovate, 4 to 15 cm long, 0.9 to 6.0 cm broad, glabrous on both sides, with 1 to 8 (typically 7) prominent nerves running to or almost to the leaf apex; cauline bract green, leaf-like, persistent; peduncles axillary, solitary, slender, glabrous, arcuate, typically 2 (rarely 1-5)-flowered; pedicels slender, glabrous; filaments minutely papillose, inserted

near middle of perianth tube; anthers 2.1-3.5 mm long (typically 2.4-3.1 mm long); style length varies from 1.7-10.0 mm (typically less than 8.0 mm long); berry dark blue, usually less than 8 mm in diameter.

Representative Specimens: ALABAMA: LEE CO. Wet woodlands, 4 Apr 1963, Hayes 142. ILLINOIS: FRANKLIN CO. 3 mi w of Benton, oak-hickory woods, April 1972, Adams, s.n.; 2 mi n, 1/2 mi e of Ewing, Robinson farm, wooded hillside, 24 Apr 1972, Harmon 27. HARDIN CO. Rock Creek Valley, T11S, R9E, "closed" woods on lower slopes of valley and open dry woods on n slope, 3 May 1949, Bailey & Swayne 673. JACKSON CO. Giant City State Park, rich mesophytic woods, 18 Apr 1954, Mohlenbrock 2092; between Murphysboro and Etherton, along roadside, 23 May 1954, Mohlenbrock 2138; Giant City State Park, sandstone bluff, 25 Apr 1959, Sands 535. JEFFERSON CO. 5 mi sw of Mt Vernon, 1 mi w of State Hwy 148, slight w slope, under oak and hickory, 7 May 1972, Agee 20; 3 mi n and 2 mi w of Sesser, rich, moist, oak-hickory woods, 6 May 1972, Williams 46. JOHNSON CO. Ferne Clyffe, bluff top, w-facing slope, 27 June 1963, Bollwinkel & Windler FC 1; Ferne Clyffe, bluff top, dry, rocky outcrop, w-facing, 25 June 1963, Bollwinkel & Windler FC 46. POPE CO. Belle Smith Springs, e slope, dense woods, 27 May 1956, Carter 33; Lusk Cr, moist woods, 21 May 1966, Hopkins 130; Dixon Springs, rich woods, 16 Apr 1954, Mohlenbrock 2099; near Martha's woods along Little Lusk Cr, very dry, sandy upland woods, 11 May 1968, Schwegman 1666. KENTUCKY: MARSHALL CO. Near e fork of Clarks River, e of Benton, moist woods, 29 Jul 1963, O'Dell & Windler 1233. NEW JERSEY: GLOUCESTER CO. Along streamlet tributary to South Branch Timber Creek, loamy, wooded w slope, 7 May 1921, Long 24003. NORTH CAROLINA: FORSYTH CO. 4.4 mi n of Kernersville, wooded slope, 17 May 1958, Ahles & Britt 40732. WAKE CO. Little River, Mitchells Mill, 2 mi ne of Rolesville, 22 Sept 1966, Windler 1603. VIRGINIA: BEDFORD CO. No locality data, 20 May 1872, Curtiss, s.n.

3. Polygonatum canaliculatum (Muhl.) Pursh, Fl Am. Sept. 1: 234, 1814.

Perennial herb, 5-20 dm high; rhizome stout, often branched, deeply buried; stem usually stout and arching, glabrous; leaves alternate, amplexicaulous, varied in shape, ovate-lanceolate, elliptic-lanceolate, oblong-lanceolate, or broadly oval, 6 to 25 cm long, 1.5 to 13 cm broad, glabrous on both sides, with 7 to 22 or more major nerves prominent the full length of the leaf, the major nerves alternating with other fainter but distinct nerves, leaf margin undulate or "puckered"; cauline bract green, leaf-like, persistent; peduncles coarse, flattened, often stiff and wiry, usually long and arched, glabrous, 1- to 15-flowered (typically 3 or more); pedicels flattened, glabrous; filaments smooth to densely papillose, inserted near the middle of perianth tube; anthers 3.4-4.8 mm long (usually 3.9-4.2 mm long); style length variable from 3.0-10.8 mm (typically 8.8-10.8 mm); berry dark blue, 8 to 12 mm in diameter.

Representative Specimens: CONNECTICUT: NEW HAVEN CO. Middlebury, Hop Swamp, 27 June 1896, Shepardson, s.n. ILLINOIS: CARROLL CO. T24N, R5E, sect 5, roadside, edge of woods, 13 Aug 1963, Verts 109. CLARK CO. Rocky Branch Nature Preserve, T12N, R12W, sects 29 & 30, 12 Jul 1969, Ebinger 8623. COLES CO. Fox Ridge State Park, T11N, R9E, sect 13, steep wooded slope, 7 June 1968, Mohlenbrock 15016. CUMBERLAND CO. Hazel Dell, extreme se corner, dry oak-

hickory woods, 12 Aug 1964, DeFilipps & Ozment 1509. HARDIN CO. Blind Hollow, 24 Apr 1954, Voigt & Mohlenbrock 2222. JACKSON CO. Fern Rocks, June 1971, French, s.n.; Hickory Ridge, w side of hill, dry woods, 15 May 1956, Gotway 38; near Boskeydell, woods, 14 Aug 1941, Hall 1033; Little Grand Canyon, mesic lowland woods and canyon ledges, 7 Aug 1967, Johnson 436; Giant City State Park, woods, 25 June 1953, Mohlenbrock 356; s of Murphysboro, GMORR, moist shaded soil, 23 Apr 1954, Mohlenbrock 2138; Lake Murphysboro, wet low woods, 18 May 1954, Mohlenbrock 2441; Lake Murphysboro, rich moist woods, 19 May 1955, Mohlenbrock 5315; Big Muddy River, 3.5 mi n of Carbondale, rich moist woods, 5 May 1956, Sands 63; Botany Preserve, Southern Illinois University, Carbondale, shaded moist woods, 27 May 1952, Voigt, s.n. JEFFERSON CO. 6 mi n of Mt Vernon, Casey Fork Bottoms, Idlewood Rd, 28 Apr 1964, Estes 87; 5 mi n of Mt Vernon, moist woodland, 30 May 1965, Estes 248. JO DAVIESS CO. Apple River Canyon State Park, 30 May 1965, Hinkley, s.n. JOHNSON CO. Heron Pond, 3 mi s of Vienna, moist woods, 30 Apr 1969, White 965. LAKE CO. Illinois Beach State Park, shaded grass covered dunes, 12 June 1966, Brouillard 1; Miltmore Lake, moist shoreline, 16 June 1966, Moran 8. MACON CO. e shore of Lake Decatur, about 250 m n of NWRR, rich leaf mold in woods, 30 May 1972, Shildneck C-3720. MONROE CO. s of Fults, T4S, R10W, talus, base of limestone bluff, 11 May 1952, Bailey & Swayne 2248A. OGLE CO. Lowden State Park, moist low woods, 18 July 1964, DeFilipps & Ozment 210. PERRY CO. United Electric Fidelity Coal Co., w of DuQuoin, black locust plot, 21 May 1963, Baker, s.n.; near Matthews along "Old Mud Line," 9 May 1954, Mohlenbrock 2388. POPE CO. Bay Bottoms, T12S, R5E, sect 9, rich mesic woods, 27 Aug 1952, Bailey & Swayne 2861; Jackson Hollow, T11S, R5E, sect 31, closed beech-maple woods, 17 Aug 1950, Swayne & Bailey 1278. ST. CLAIR CO. Vic of 3-Forks, rich shaded soil, 10 Sept 1960, Neill 15286; vic of Imbs Station, edge of woods, 8 July 1967, Neill 15716; STEPHENSON CO. Lake Le-Aqua-Na State Park, moist woods, 19 July 1964, DeFilipps & Ozment 293. UNION CO. Union Co.-Johnson Co. line, Drapers Bluff, T11S, R2-3E, sects 31-36, oak-hickory woods, top of bluff, 29 May 1952, Bailey & Swayne 2421; Hanging Rocks, e of McClure, T13S, R2W, sect 31, chert bluff, 19 June 1952, Bailey & Swayne 2556; Pine Hills, Mar 1953, Mohlenbrock s.n. WABASH CO. n of Mt Carmel, T1N, R12W, oak-hickory woods on hilltop, 16 Aug 1951, Bailey & Swayne 1728. WASHINGTON CO. Near nashville, wooded hillside, 12 May 1951, Bailey & Swayne 1393. WHITE CO. 1 mi n of Emma, low woods, 20 June 1958, Voigt & Weber 2021. IOWA: DES MOINES CO. 3 mi nw of jct of Hwys 34 & 406, wooded country lane, 26 Aug 1967, Johnson, s.n. KENTUCKY: LYON CO. Along roadside to Sugar Bay, moist woods, 22 Apr 1967, Riggs & DeVillez 62. MARSHALL CO. e fork of Clarks River, e of Benton, woods, 29 July 1962, O'Dell & Windler 1237. MICHIGAN: KALAMAZOO CO. Schoolcraft Twp, T45, R11W, sw 1/4 sect 18, beech-maple woods, 6 May 1971, Krusel, s.n. MISSOURI: CHRISTIAN CO. Near Garrison, rocky wooded banks of Swan Cr, 20 Apr 1956, E J Palmer 62021A, 62021B. JASPER CO. 1 mi ne of Joplin, along Turkey Cr, steep rocky n-facing hillside, 10 June 1964, E J Palmer 57780. POLK CO. 6 mi ne of Rondo, along creek, rocky wooded bluffs, 23 May 1956, E J Palmer 62519.

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ANOMALOUS PINK TILL

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Abstract - Anomalous pink till occurs intercalated sporadically with the Batestown Till Member of the Wedron Formation (Wisconsin Glaciation) in the Urbana and Danville, Illinois, areas. Field observations and laboratory analyses show that the pink till is significantly distinct from the Batestown and imply a combination of shearing, weathering, and glacial transportation as a mode of origin. The pink till is very calcareous and sandy, but differs from similar anomalous pink tills, noted throughout the continental glaciated region. The till is generally found with extremely weathered crystalline cobbles.

Sporadically distributed pinkish zones have occasionally been observed intercalated within brownish-yellow to gray till in the Champaign-Urbana area. The till is Batestown Till Member of the Wedron Formation (Johnson, et al.) which is Wisconsinan (Woodfordian substage) in age. It is the uppermost till in the area. Anomalous pink till zones have also been noted in the Batestown Till near Danville, 30 miles east of Urbana. The pink till in both locations is very calcareous and is found concomitantly with extremely friable crystalline cobbles.

The origin of these pink till zones or of similar occurrences in other geographic areas is not definitely known. Possibilities include emplacement as sheared zones of older pink till (e.g. Bretz, 1955), such as the pink Hillery Till, paleosol (Lessig and Rice, 1962), outwash, or bedrock (Gadd, 1959); weathering in-situ; or some combination of the above.

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URBANA ANOMALOUS PINK TILL DESCRIPTION

A sewer trench excavation on the University of Illinois campus provided a brief opportunity for examination of the anomalous pink till. The trench was approximately 50 meters long, 2 deep, and 2½ wide. The pink zones were scattered throughout, beginning at a depth of one meter and became slightly more common with depth. The greatest occurrence was near the center of the ditch on the north wall; this face was chosen as a sample area and is shown schematically in Figure 1. An

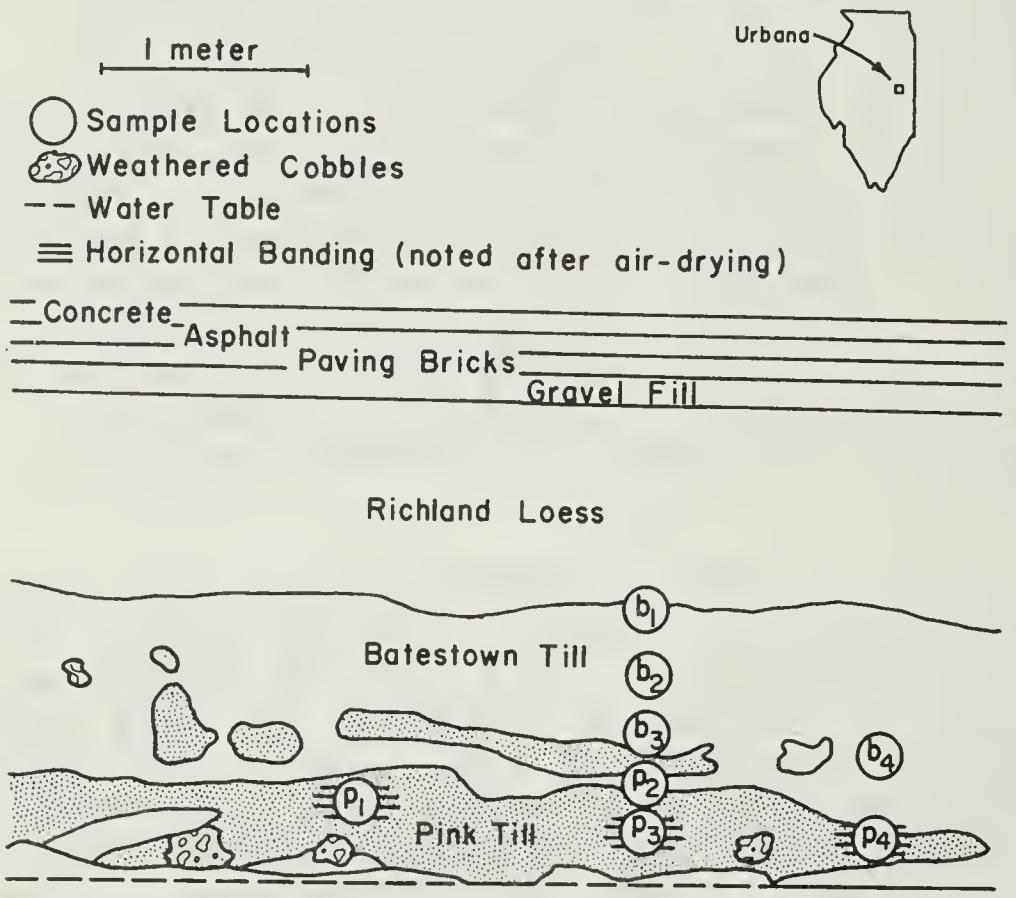

Figure 1. Cross section of anomalous pink till occurrence in Urbana, Illinois.

additional pink till zone on the south face was sampled. A small (4cm x 16cm) pink till zone was also discovered and sampled at the base of the Batestown in an abandoned strip mine near Danville.

The top soil in the study area had been completely removed by previous construction; no A horizon was present. The top 25 to 30cm consisted of a gravel subbase overlain by a brick pavement (north wall only), asphalt, and concrete at the ground surface. The upper meter of soil is yellow Richland Loess. The loess is permeated throughout by root structures and fractures.

Immediately below the loess (the contact is sharp) is the brownish-yellow Batestown Till. The till is massive; no significant structural features were noticeable. There was not a great deal of coarse (gravel-size or greater) material in the sample face. Nine pebbles greater than 3 cm in diameter were present; 2 of the pebbles were dolomites, one a well-indurated basalt, and 5 felsic crystallines. Four of the crystallines were so friable that they fell apart in the hands upon removal. The fifth was well-indurated, but was over a meter from the nearest pink zone. The friable crystallines were either in or adjacent to the pink till. Johnson (pers. comm.) has observed similar occurrences of weathered crystallines in pink zones in other campus excavations. The Danville sample had similar weathered cobbles.

The pink till appeared to lack structure, but after air drying, horizontal banding was visible in samples P_1, P_3, and P_4. The pink tills were also more friable than the surrounding Batestown Till. These pink zones also varied normal to the sample face. Sample P_2, for instance, was brownish-yellow on the face, but was pinkish-gray 2 or 3 centimeters into the face. The contact between tills was sharp and easily distinguishable. The overall pattern is not inconsistent with that of the shear zones noted by Bretz (1955). The water table approached the bottom of the ditch; standing water was evident in several places even though rain had not recently fallen.

EXPERIMENTAL PROCEDURE

Selected samples of anomalous pink till and Batestown Till were taken. The samples were then air dried and the color described with the use of Munsell color charts. The small Danville sample was also so described as well as the control sample (Hillery Till). The pink till varies between 5YR 7/2 (pinkish-gray) and 5YR 7/3 (pink); the Danville sample was 5YR 4/3 (reddish-brown). Batestown Till varies between 2/5Y 7/4 (pale yellow) and 10YR 7/3 (very pale brown).

Grain-size analysis was run using the method of Shepps (1953). The minus 230 mesh (U.S. Standard) was used for silt-clay analysis by ASTM hydrometer method (Lambe, 1951). Pink zones are sandier than the surrounding Batestown Till except for Sample 2, which contained some Batestown material; results are shown in Figure 2. The Hillery Till control sample showed a grain-size distribution of (31, 50, 19; sand, silt, clay) which compares with a reported mean of (30, 42, 28) (Johnson, et al, 1971) (see Fig. 2).

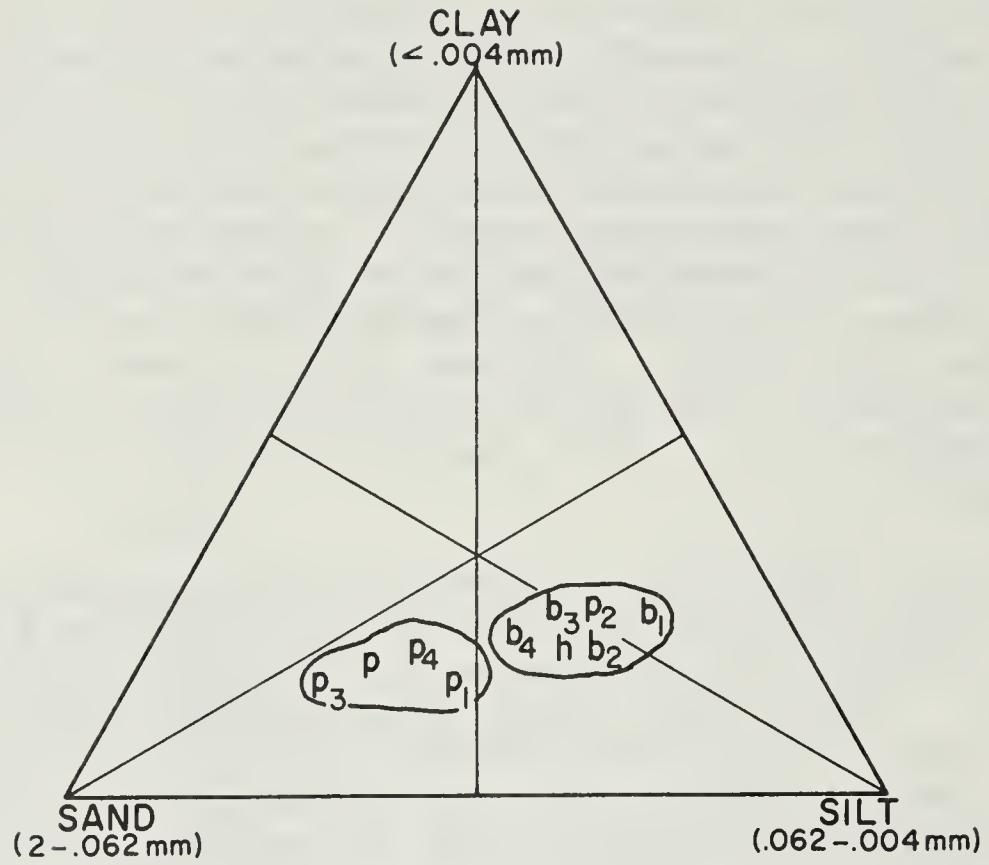

Figure 2. Grain-size analysis. p, b, and h refer to pink, Batestown, and Hillery tills, respectively.

Carbonate analyses were run on a Chittick apparatus (Dreimanis, 1962). The results are shown in Figure 3. Both calcite and dolomite contents were 2 or 3 times greater in the pink till than in the Batestown. The pink till was approximately 50% carbonate (10% calcite and 40% dolomite) and was quite uniform in content; the Batestown ranged from 7 to 25% carbonate, the later value from a sample in close proximity to a pink till zone. The Danville sample was composed of 14% calcite and 64% dolomite. (See Fig. 3).

Clay analysis of the less than 2 micron fraction was performed by x-ray diffraction techniques. Duplicate slides were made from each sample, and the data presented are from the slide giving the strongest peaks and thus the best precision. In each case the duplicates were in agreement, within experimental error. The clay mineral composition also shows a distinct difference between the Batestown and the pink till. The average composition of samples P, P_1, P_3, and P_4 is (16, 65, 19; expandables, illite, chlorite). Batestown Till has an average clay mineral composition of about (8, 77, 15). Sample B_1 is apparently a mixture of Batestown Till and the overlying Richland Loess, as can be seen on Figure 1.

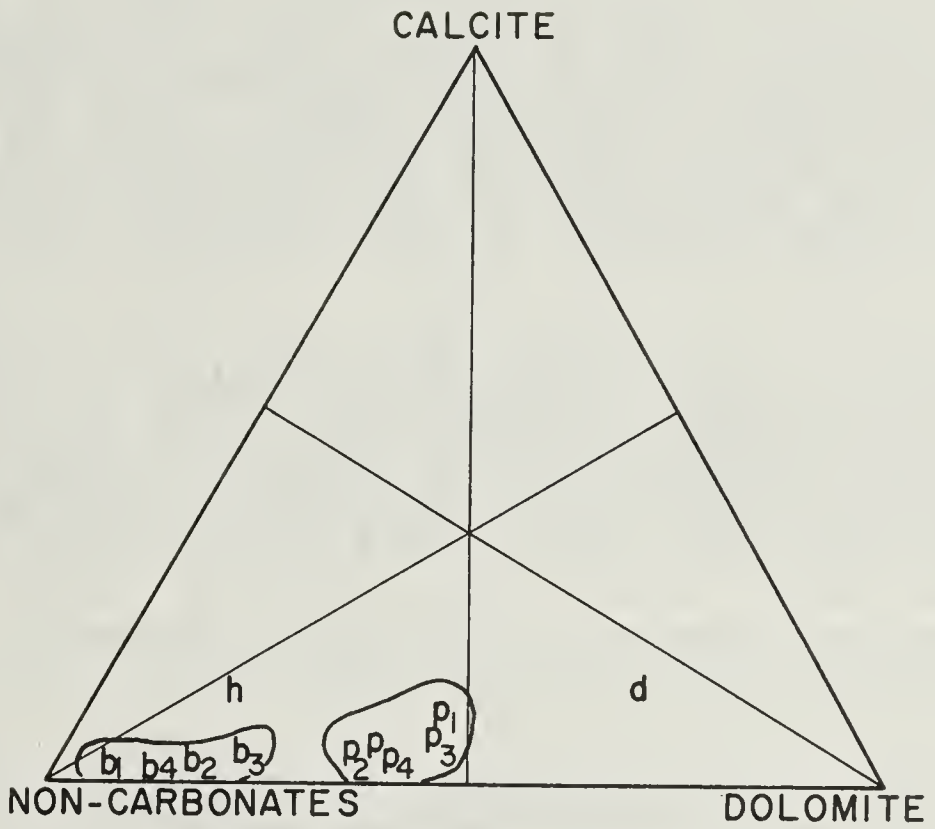

Figure 3. Carbonate analysis. p, b, and h refer to pink, Batestown, and Hillery tills, respectively. d refers to the pink till sample from Danville, Illinois.

Iron and manganese concentrations were determined by X ray fluorescence analysis using the powder method. Approximately 3 grams of the -230 mesh sample was placed in a small polyethylene cup. The top was covered with mylar film and the cup then inverted and placed in the spectrometer. USGS standard PCC-1 was used as a reference. Magnetite grains were observed in both Batestown and pink till samples. The Batestown has an iron concentration, expressed as Fe_2O_3, ranging from 3.15% to 3.56% and a manganese concentration, expressed as MnO, ranging from 0.043% to 0.048% in the samples analyzed. In contrast, the pink till has a lower iron concentration, ranging from 1.93% to 2.34%, and a lower manganese concentration, ranging from 0.024% to 0.031%.

Finally, a microscopic examination of the coarse (plus 10 mesh) fraction of the anomalous pink till revealed epidote and chlorite in a very weathered condition, plagioclase, and quartz. There was very little carbonate present in this fraction. The cause of the pink color was not evident, but presumably results from the weathering of the ferromagnesium silicates or magnetite. Staining of individual grains was not observed.

PINK OR RED TILLS IN ILLINOIS

Extensive areas of pinkish tills have been noted in Illinois. The Hillery Till (Illinoian in age) is present in east-central Illinois, but is at a significant depth below the surface in the campus area (Johnson, personal communication). Willman and Frye (1970) list the slightly sandy pinkish-gray Glenburn Till in the Shelbyville (Wisconsinan) drift and a thin pinkish Cerro Gordo Till at the base of the Batestown. None of these tills, however, closely resemble the anomalous pink till.

Hoberg (1953) reports that the thrusting of loess over loess in northern Illinois Woodfordian drift as being evidenced by a "thin, discontinuous smear of pink Wisconsin till." There are abundant references to pinkish tills in northern and central Illinois. The Tiskilwa, Argyle, and Capron tills (Wisconsinan) are characteristically red or pink in color (Frye, et al, 1969). Pink tills have not been reported in the Champaign or Urbana drifts.

SOME OTHER OCCURRENCES OF PINK OR RED TILL

Gadd (1959) describes the pre-Wisconsinan Becancour Till in the Province of Quebec, Canada. This till is a brick-red sandy clay till. The color is derived from sheared fragments of underlying red shale. The till is strongly calcareous and the carbonate content decreases with increasing clay content. Crystalline cobbles are also present.

White, in Delong and White (1963), notes streaks of "maroon" till in early Wisconsinan age drift in east-central Ohio. White, et al, (1969) described occurrences of an anomalous dark reddish brown clayey till in northwestern Pennsylvania. The occurrences varied from fine streaks to one 1½ x 3 meter mass; this till was very calcareous and appeared unweathered. Glacial pebbles were present, but were not described. Finally, Kelly and Baker (1966) described anomalous, calcareous "orange" zones in normally buff-colored till in east-central North Dakota. These zones are generally less than a square foot in cross sectional area; the orange till is composed of blocks of an older till picked up and redeposited in a younger drift.

DISCUSSION

A viable theory for the genesis of the observed pink till must explain the following:

1. the presence of the friable crystalline cobbles
2. the mineralogy
3. the coarseness of the matrix, compared to the Batestown Till
4. the sporadic nature of occurrence

The friability of the glacial cobbles in the till indicate considerable weathering, but normal in-situ weathering of the Batestown is not a valid mechanism of formation. The increase of the carbonates and the sand fraction with depth, the irregular pattern of occurrence, and the glacial cobbles contradict normal processes. If the pink zones had been formed by downward percolation of groundwater and simultaneous alteration, an increase in clays with depth would be expected, particularly in the minus ½ micron size (Willman, et al, 1966). Vertical grain-size variation caused by weathering generally results in leaching of carbonates, clay eluviation and illuviation, and in-situ decomposition of silicates decreasing downwards.

The clay mineralogy substantiates the hypothesis that the pink till is not from the same source as the Batestown Till. The clay mineral composition is distinctly different for the two materials; this difference is too large to be explained by anything other than different sources. The illite composition, in particular, indicates different sources. The process of weathering results in the conversion of chlorite to expandable clay minerals. It may be possible, therefore, to consider the ratio of expandable to chlorite a crude weathering index. The ratio for the pink till is about 0.8, while that for the Batestown Till is about 0.5. This would imply that the pink till is more weathered than the Batestown. This, however, is not conclusive evidence, as one must assume that the initial ratios of expandables to chlorite for the two materials were equal.

A shearing hypothesis is not inconsistent with the pink till geometry, but at present there are no known older tills with the observed grain-size, clay mineralogy and carbonate composition. The mechanism of transportational stacking (Moran, 1971) appears to be a feasible physical process. The Becancour Till (Gadd, 1959) is very similar to the observed pink till, but is over 800 miles away. No other tills, paleosols, or bedrock now known are sufficiently close either in their physical characteristics or geographic area to be considered a parent source for the Urbana anomalous pink till.

The origin of this till is evidently some combination of weathering, shearing and glacial transportation, the exact nature of which is still unknown. Further investigation into this process is planned when new field exposures of the pink till become available.

ACKNOWLEDGMENTS

The writer is indebted to Professors George W. White and W. Hilton Johnson for their encouragement. Professor Johnson originally suggested this study and further investigations are being planned under his aegis. Dennis Coleman and H. D. Glass of the Illinois State Geological Survey conducted clay mineralogy and iron analyses.

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THE INFLUENCE OF OSMOTIC PRESSURE IN TESTS FOR ALLELOPATHY

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ABSTRACT - The influence of osmotic pressure on the early growth of seedlings used in tests for allelopathy was determined for two bioassay systems. Bromus rigidus (Ripgut Grass) was used to test the bioassay procedures against solutions of sucrose, mannitol, KCl, $NaNo_3$, and multiples of full strength Hoagland's solution. Significant growth reductions were observed with concentrations as low as 75 milliosmoles. Aqueous extracts of Adenostoma fasciculatum (Chamise) foliage and dead Brassica nigra (Black Mustard) leaves produced significant retardation of growth with concentrations of 25 milliosmoles.

INTRODUCTION

Allelopathy or the biochemical suppression of one plant by another has been a subject of increasing ecological interest. Several recent studies (Muller et al., 1968, Wilson and Rice, 1968; McPherson and Muller, 1969; del Moral and Muller, 1970; and Bell and Muller, 1973) have utilized various laboratory bioassay procedures to elucidate an allelopathic mechanism. These bioassay methods generally involve the direct use of plant tissue or the application of water extracts of suspected phytotoxic material. The suppression of some growth or germination response has been cited as evidence in favor of an allelopathic influence. None of the recent papers, however, have considered the effects of the osmotic pressure exerted by these extracts. Interference with water absorption may be the direct effect causing the reduced growth. The present study was undertaken to evaluate the relative influences of osmotic concentration and phytotoxic suppression in tests for antibiosis.

MATERIALS AND METHODS

Two laboratory bioassay methods were employed in this study, the first designated as the sponge bioassay and the second designated as the sand bioassay. The sponge bioassay technique involved the use of 100 x 15 mm petri dishes with seedbeds of 50 x 50 x 3 mm cellulose sponge covered with filter paper. Moistening was accomplished by immersing the sponge in the solution

to be tested and shaking off the excess solution. Test seeds were soaked for 2 hours in the appropriate solution before planting. Following soaking, 10 seeds were planted in two parallel rows on the edge of the seedbed to allow continued contact with solution as the radicle emerged from the caryopsis. Each plate was covered with parafilm to protect against desiccation. Measurement of radicles to the nearest mm followed 48 hr of incubation in the dark at a constant 25°C.

The sand bioassay employed similar plastic petric dishes with 50 g addition of sand as the seedbed. The sand mixture used was standardized as that particle fraction collected between 1.0 mm and 0.1 mm standard soil sieves from plaster sand. Twenty seeds were planted radially and 10 ml of the test solution was pipetted into the sand. Incubation and measurement of radicle growth was accomplished as before.

Field-collected seeds of Bromus rigidus Roth. was used as the assay species. This introduced Mediterranean grass species was chosen for its ease of collection, high germination percentage, and uniform early growth.

Solutions tested were prepared in a graduated series of osmotic pressure and measured on a Fiske Model G62 osmometer. Materials tested include solutions of sucrose, Mannitol, KCl, $NaNO_3$, and multiples of full strength Hoagland's solution. Phytotoxic materials included water extracts of dead Brassica nigra leaves (Bell and Muller, 1973) and living Adenostoma fasciculatum foliage (McPherson and Muller, 1970). Each sample was tested in triplicate and each bioassay was completed in triplicate. The data were analyzed by the technique of the honestly significant differences (Steele and Torrie, 1960).

Table 1. Effect of osmotic concentration (O.C. in milliosmoles) on radicle growth of Bromus rigidus in sponge bioassay (mm after 48 hrs.).

O.C.	Hoagland's	Hoagland's	$NaNO_3$	KCL	Sucrose	Mannitol
0	16.3±2.0	16.3±1.8	17.1±2.3	16.0±2.0	16.2±2.1	16.9±2.4
25	14.5±2.1					
50	12.9±2.1		14.0±2.1	14.2±2.0	11.4±2.2	13.7±2.0
75	11.3±2.3					
100	10.5±1.9		10.4±2.3	12.1±1.5	7.5±2.0	9.5±1.9
125		10.2±1.9				
150		8.7±2.2				
175		7.6±1.6				
200		6.6±1.4	6.5±1.9	7.6±1.1	2.0±1.2	5.1±1.2
300			2.5±1.3	4.4±1.2	1.1±0.0	2.3±0.8
400			1.1±0.0	2.2±0.8	1.0±0.0	1.2±0.0
500			0.0±0.0			0.0±0.0
HSD						
.05	4.6	4.0	3.6	3.0	3.0	3.2

RESULTS

The effect of osmotic concentration on early radicle growth in Bromus rigidus is observed in both the sponge bioassay (Table 1) and the sand bioassay (Table 2). Seedling growth was inversely proportional to osmotic concentration. It is evident that radicle growth was significantly inhibited in osmotic concentrations as low as 75 milliosmoles (approximately 1.7 atm). Suppression of growth was even greater when the large molecule non-electrolytes were used as the osmoticant. An uptake of the ions in the electrolyte tests, followed by a more rapid osmotic uptake of water, most likely resulted in the apparent differences in growth retardation. Greater water uptake also probably contributed to the difference in growth achieved in the two bioassay types. A greater absorptive surface was presented by the sand bioassay since the seeds were planted into the sand medium and surrounded by the test solution.

Table 2. Effect of osmotic concentration (O.C. in milliosmoles) on radicle growth of Bromus rigidus in the sand bioassay (mm after 48 hrs.).

O.C.	Hoagland's	Hoagland's	$NaNO_3$	KCL	Sucrose	Mannitol
0	18.5±2.3	18.2±2.3	18.0±2.5	18.1±2.5	18.4±2.1	18.2±2.6
25	17.1±2.0					
50	15.3±2.2		14.9±2.5	15.8±2.4	14.1±2.1	18.0±1.9
75	13.9±2.4					
100	11.3±2.1		12.0±2.4	13.6±2.6	11.7±1.9	12.7±2.1
125		9.6±1.5				
150		7.6±1.4				
175		6.4±1.2				
200		5.1±1.2		9.7±1.8	5.5±1.5	
300			3.9±1.1	6.8±1.4	1.7±0.6	
400				3.4±1.0	1.0±0.0	
500			1.0±0.0			1.1±0.0
1000			0.0±0.0			0.0±0.0
HSD						
.05	4.7	3.4	3.6	3.4	3.0	2.1

Growth retardation was also indicated in the tests with suspected phytotoxic materials (Table 3). When these data are figured as a percentage of control growth (0 O.C) and plotted against a representative osmoticant (Hoagland's solution), the resulting growth inhibitions are significantly greater than those expected by osmotic pressure alone (Fig. 1).

Table 3. Inhibitory effects of phytotoxic extracts of known osmotic concentration (O.C. in milliosmoles) on the radicle growth of Bromus rigidus (mm after 48 hrs.)

	Sponge Bioassay	Sand Bioassay	
O.C.	Brassica nigra	Brassica nigra	Adenostoma fasciculatum
0	16.9±2.1	18.4±1.9	16.6±2.6
2			13.5±2.6
28	9.5±2.1	12.9±2.0	10.7±2.3
60	6.1±1.7	10.7±1.6	
88	4.7±1.3	8.7±1.3	
118	4.2±1.0	7.6±1.2	
HSD			
.05	2.9	3.5	6.4

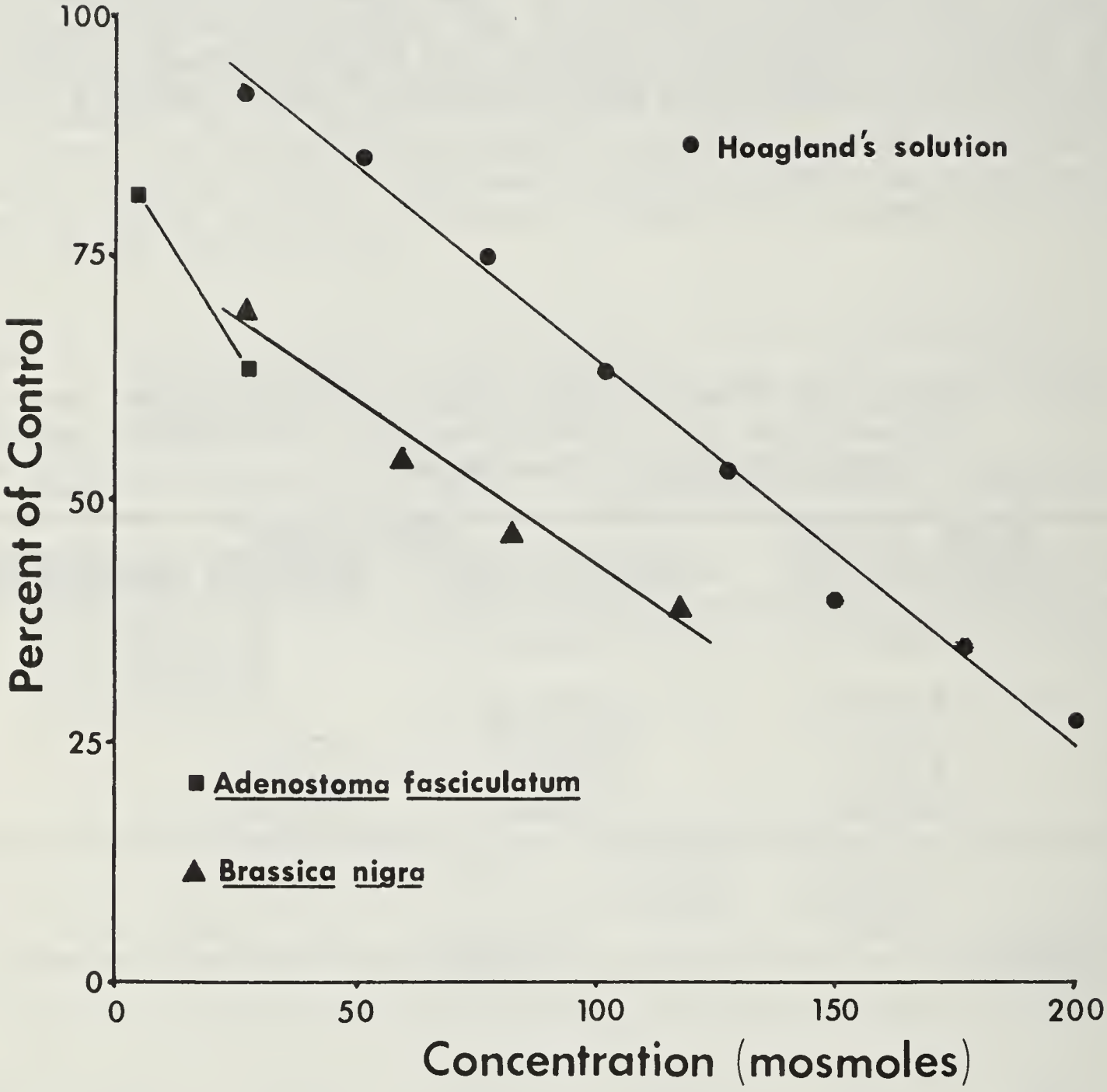

Fig. 1. Osmotic and phytotoxic inhibition of aqueous solution. Radicle growth of Bromus rigidus in concentrations of Hoagland's solution and aqueous extracts of Adenostoma fasciculatum foliage and Brassica nigra dead leaves. All points of equal osmotic concentration significantly different at 0.01 by t test.

DISCUSSION

Growth as a biological activity monitored through laboratory bioassays is subjected to several variables even in the most carefully controlled conditions. Osmotic concentrations in excess of 50 milliosmoles should be interpreted with care. The complex mixture of organic and inorganic compounds leached from plant material (Tukey, 1970) present a rather difficult question of interpretation. Some compounds, such as phenolic acids or simple sugars, may actually be stimulatory. Laboratory bioassays for suscepted phytotoxic compounds cannot stand alone as evidence for an allelopathic mechanism. Careful examination of all contributing mechanisms of interference is needed in order to properly place laboratory bioassay results into a field situation.

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NEW ALGAL RECORDS FOR LAKE COUNTY, ILLINOIS

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ABSTRACT.--This paper lists seventy-four algal species previously unreported for Lake County, Illinois. A total of seventy-six species and varieties are listed, of which eight species are new records for the state.

INTRODUCTION

Britton (1944) reported eighty-seven algal species for Lake County. Taxa reported in this paper were observed by the author from January to May, 1973 in twenty-eight collections from twenty-three different locations in the county.

These new records, together with those reported earlier (Britton, 1944; Tiffany and Britton, 1952) now comprise a list of 161 recognized algal species for Lake County. Taxa in this list are arranged in annotated form according to Smith (1950). New records for the state of Illinois are preceded by an asterisk (*). With each citation, collection site and date are given, followed by a reference which includes adequate illustration.

CHLOROPHYTA
CHLOROPHYCEAE
Volvocales

*Volvox tertius Meyer. Getz Pond, April 28, 1973. Prescott, 1962, Pl. 3, Fig. 12.

Haematococcus lacustris (Girod) Rostafinski. Stanley Field Estate, Lake Bluff, March 11, 1973. Smith, 1950, Fig. 52.

Ulotrichales

Ulothrix tenerrima Kuetzing. Ravine, Lake Forest College, May 9, 1973. Tiffany and Britton, 1952, Pl. 4, Fig. 38.

*Ulothrix tenuissima Kuetzing. Walden ravine, Lake Forest, April 8, 1973. Prescott, 1962, Pl. 67, Figs. 11, 12.

Cladophorales

Cladophora glomerata (Linnaeus) Kuetzing. Walden ravine, Lake Forest, April 8, 1973. Tiffany and Britton, 1952, Pl. 13, Fig. 93.

Rhizoclonium hieroglyphicum (Agardh) Kuetzing. Getz Pond, April 14, 1973. Tiffany and Britton, 1952, Pl. 13, Fig. 91.

Chlorococcales

*Pediastrum biradiatum Meyen. Dead River, Illinois Beach State Park, April 28, 1973. Prescott, 1962, Pl. 47, Figs. 5,6.

Pediastrum boryanum (Turpin) Meneghini var. longicorne Raciborski. Sentinel Lake, Long Grove, February 4, 1973. Tiffany and Britton, 1952, Pl. 30, Fig. 297.

Planktosphaeria gelatinosa G.M. Smith. Daniel Wright Forest Preserve, January 21, 1973. Prescott, 1962, Pl. 53, Fig. 23.

Ankistrodesmus falcatus (Corda) Ralfs. Getz Pond, April 14, 1973. Tiffany and Britton, 1952, Pl. 31, Fig. 307.
*Scenedesmus hystrix Lagerheim. Getz Pond, April 14, 1973. Prescott, 1962, Pl. 63, Fig. 12.

Zygnematales

Spirogyra porticalis (Mueller) Cleve. Dead River, Illinois Beach State Park, April 28, 1973. Tiffany and Britton, 1952, Pl. 44, Fig. 468.
Spirogyra silvicola M.E. Britton. Dead River, Illinois Beach State Park, April 28, 1973. Tiffany and Britton, 1952, Pl. 43, Fig. 456.
Spirogyra varians (Hass.) Kuetzing. Dead River, Illinois Beach State Park, April 28, 1973. Tiffany and Britton, 1952, Pl. 44, Fig. 464.
Roya obtusa (Brébisson) W. and G.S. West. Stanley Field Estate, Lake Bluff, March 11, 1973. Tiffany and Britton, 1952, Pl. 51, Fig. 533.
Closterium gracile Brébisson var. elongatum W. and G.S. West. Getz Pond, January 21, 1973. Tiffany and Britton, 1952, Pl. 52, Fig. 557.
Closterium moniliferum (Bory) Ehrenberg. Getz Pond, January 21, 1973. Tiffany and Britton,1952, Pl. 52, Fig. 549.
Closterium strigosum Brébisson. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 51, Fig. 545.
Pleurotaenium trabecula (Ehrenberg) Naegeli. Sentinel Lake, Long Grove, February 4, 1973. Tiffany and Britton, 1952, Pl. 55, Fig. 609.
*Cosmarium pseudoconnatum Nordst. Stanley Field Estate, Lake Bluff, March 11, 1973. West and West, 1908, Pl. LXVII, Figs. 19-21.
Cosmarium reniforme (Ralfs) Archer. Roadside ditch, Hawley Street, east of Gilmer Road, Fremont, March 15, 1973. Tiffany and Britton, 1952, Pl. 53, Fig. 586.

EUGLENOPHYTA
EUGLENOPHYCEAE
Euglenales

Euglena acutissima Lemmermann. Small pond along Brandenburg Road, 0.3 miles west of U.S. 12, March 15, 1973. Tiffany and Britton, 1952, Pl. 87, Fig. 1005.
Euglena gracilis Klebs. Small pond along Brandenburg Road, 0.3 miles west of U.S. 12, March 15, 1973. Tiffany and Britton, 1952, Pl. 87, Fig. 1012.
Euglena spiroides Lemmermann. Water-filled ditch north of EJ&E railroad tracks, Lake Forest, May 10, 1973. Tiffany and Britton, 1952, Pl. 87, Fig.1016.
Euglena tripteris (Dujardin) Klebs. Tower Lake, April 14, 1973. Tiffany and Britton, 1952, Pl. 87, Fig. 1014.
Euglena viridis Ehrenberg. Cement pool, east of Lake Road, Lake Forest, April 22, 1973. Tiffany and Britton, 1952, Pl. 87, Fig. 1009.
*Phacus caudatus Huebner. Small pond along Brandenburg Road, 0.3 miles west of U.S. 12, March 15, 1973. Prescott, 1962, Pl. 87, Fig. 13.
Phacus pyrum (Ehrenberg) Stein. Fox Lake, April 14, 1973. Tiffany and Britton, 1952, Pl. 88, Fig. 1021.
Trachelomonas acanthostoma (Stokes) Deflandre. Large pond on west side of U.S. 12, between Sullivan Lake Road and Brandenburg Road, March 15, 1973. Weik and Mohlenbrock, 1963, Pl. I, Fig. 18.
Trachelomonas coronata Swirenko. Small pond along Brandenburg Road, 0.3 miles west of U.S. 12, March 15, 1973. Weik and Mohlenbrock, 1963, Pl. I, Fig. 8.

Trachelomonas intermedia Dangeard. Getz Pond, April 14, 1973. Weik and Mohlenbrock, 1963, Pl. I, Fig. 9.
Trachelomonas lacustris Skvortzow. Volo Bog, May 2, 1973. Weik and Mohlenbrock, 1963, Pl. II, Fig. 31.

CHRYSOPHYTA
XANTHOPHYCEAE
Heterotrichales

*Tribonema affine G.S. West. Daniel Wright Forest Preserve, January 21, 1973. Prescott, 1962, Pl. 96, Figs. 7-9.
Tribonema bombycinum (C.A. Agardh) Derbés and Solier. Daniel Wright Forest Preserve, January 21, 1973. Tiffany and Britton, 1952, Pl. 57, Fig. 648.
Tribonema minus (Wille) Hazen. Daniel Wright Forest Preserve, January 21, 1973. Tiffany and Britton, 1952, Pl. 57, Fig. 650.
Tribonema utriculosum (Kuetzing) Hazen. Water-filled ditch on west side of St. Mary's Road between Rt. 60 and Rt. 176, March 28, 1973. Tiffany and Britton, 1952, Pl. 57, Fig. 647.

Heterosiphonales

Vaucheria geminata (Vaucher) DeCandolle. Water-filled ditch north of Beach Road, near entrance to Illinois Beach State Park, May 11, 1973. Tiffany and Britton, 1952, Pl. 37, Fig. 385.
Vaucheria repens Hassall. Cement pool east of Lake Road, Lake Forest, April 22, 1973. Tiffany and Britton, 1952, Pl. 37, Fig. 383.

CHRYSOPHYCEAE
Chrysomonadales

Synura uvella Ehrenberg. Getz Pond, January 21, 1973. Tiffany and Britton, 1952, Pl. 81, Figs. 393-940.

BACILLARIOPHYCEAE
Centrales

Melosira varians C.A. Agardh. Tower Lake, April 14, 1973. Tiffany and Britton, 1952, Pl. 59, Fig. 673.
Stephanodiscus astraea (Ehrenberg) Grunow. Fox River, April 14, 1973. Tiffany and Britton, 1952, Pl. 60, Fig. 676.
Stephanodiscus niagarae Ehrenberg. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 60, Fig. 680.
Actinocyclus niagarae H.L. Smith. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 58, Fig. 666.

Pennales

Tabellaria fenestrata (Lyngbye) Kuetzing. Tower Lake, April 14, 1973. Tiffany and Britton, 1952, Pl. 61, Figs. 691, 693.
Meridion circulare (Greville) C.A. Agardh. Water-filled ditch east of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 61, Figs. 689-690.
Diatoma hiemale (Lyngbye) Heiberg. Getz Pond, April 28, 1973. Tiffany and Britton, 1952, Pl. 61, Fig. 684.

Diatoma vulgare Bory. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 61, Figs. 686-687.

Fragilaria crotonensis Kitton. Water-filled ditch east of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 62, Fig. 703.

Fragilaria pinnata Ehrenberg. Getz Pond, January 21, 1973. Tiffany and Britton, 1952, Pl. 62, Fig. 700.

Fragilaria virescens Ralfs. Water-filled ditch east of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 62, Fig. 702.

Synedra acus Kuetzing. Daniel Wright Forest Preserve. February 4, 1973. Tiffany and Britton, 1952, Pl. 63, Fig. 720.

Synedra acus Kuetzing var. radians (Kuetzing) Hustedt. Getz Pond, April 14, 1973. Tiffany and Britton, 1952, Pl. 63, Fig. 721.

Synedra tenera W. Smith. Tower Lake, April 14, 1973. Tiffany and Britton, 1952, Pl. 63, Fig. 719.

Synedra ulna (Nitzsch) Ehrenberg. Daniel Wright Forest Preserve, February 4, 1973. Tiffany and Britton, 1952, Pl. 63, Fig. 713.

Synedra ulna (Nitzsch) Ehrenberg var. aequalis (Kuetzing) Hustedt. Skokie Ditch, north of Rt. 176, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 63, Fig. 714.

Asterionella formosa Hassall. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 63, Fig. 709.

Rhoicosphenia curvata (Kuetzing) Grunow. Small stream running under Rt. 176, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 65, Fig. 753.

Cocconeis placentula Ehrenberg var. lineata (Ehrenberg) Cleve. Dead River, Illinois Beach State Park, April 28, 1973. Tiffany and Britton, 1952, Pl. 64, Fig. 736.

Navicula cuspidata Kuetzing. Water-filled ditch north of EJ&E railroad tracks, Lake Forest, May 10, 1973. Tiffany and Britton, 1952, Pl. 68, Fig. 789.

Navicula rhyncocephala Kuetzing. Water-filled ditch east of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 67, Fig. 782.

Pinnularia major (Kuetzing) Wm. Smith. Marshy area west of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 68, Fig. 795.

Pinnularia viridis (Nitzsch) Ehrenberg. Volo Bog, May 2, 1973. Tiffany and Britton, 1952, Pl. 70, Fig. 809.

Caloneis silicula (Ehrenberg) Cleve. var. gibberula (Kuetzing) Cleve. Marshy area west of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, 1952, Pl. 65, Fig. 746.

Caloneis trinodis (Lewis) Boyer. Marshy area west of C&NW railroad tracks, northwest of Sheridan and McKinley Roads, Lake Bluff, February 25, 1973. Tiffany and Britton, Pl. 79, Fig. 919.

Gomphonema acuminatum Ehrenberg. Getz Pond, January 21, 1973. Tiffany and Britton, 1952, Pl. 72, Fig. 830.

Cymbella cistula (Hemprich) Grunow. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 74, Fig. 861.

Cymbella lanceolata (Ehrenberg) Van Heurck. Dead River, Illinois Beach State Park, April 28, 1973. Tiffany and Britton, 1952, Pl. 74, Fig. 872.

Cymbella ventricosa Kuetzing. Large pond on west side of U.S. 12, between Sullivan Lake Road and Brandenburg Road, March 15, 1973. Tiffany and Britton, 1952, Pl. 74, Fig. 871.

Epithemia turgida (Ehrenberg) Kuetzing. Pistakee Lake, March 15, 1973. Tiffany and Britton, 1952, Pl. 75, Fig. 876.

Epithemia zebra (Ehrenberg) Kuetzing. Getz Pond, January 21, 1973. Tiffany and Britton, 1952, Pl. 75, Fig. 882.

Rhopalodia gibba (Kuetzing) Mueller. Getz Pond, April 14, 1973. Tiffany and Britton, 1952, Pl. 75, Fig. 884.

PYRROPHYTA
DINOPHYCEAE
Peridiniales

Peridinium bipes Stein. Getz Pond, April 28, 1973. Tiffany and Britton, 1952, Pl. 85, Figs. 988-991.

CYANOPHYTA
MYXOPHYCEAE
Chroococcales

Merismopedia convoluta Brébisson. Sentinel Lake, Long Grove, February 4, 1973. Tiffany and Britton, 1952, Pl. 91, Fig. 1051.

Oscillatoriales

Oscillatoria amoena (Kuetzing) Gomont. Stanley Field Estate, Lake Bluff, March 11, 1973. Tiffany and Britton, 1952, Pl. 93, Fig. 1073.

Oscillatoria geminata Meneghini. Getz Pond, January 21, 1973. Tiffany and Britton, 1952, Pl. 94, Fig. 1087.

*Oscillatoria subbrevis Schmidle. Getz Pond, January 21, 1973. Prescott, 1962, Pl. 107, Fig. 23.

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LEAD CONTAMINATION OF SOILS AND PLANTS ALONG HIGHWAY GRADIENTS IN EAST CENTRAL-ILLINOIS[1]

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ABSTRACT

One annual and one perennial species in each of three plant families and soils from 0-10 and 10-20 cm around each plant were examined for total lead content by atomic absorption spectrophotometry. Samples were taken along a highway in east-central Illinois with estimated traffic volume of 12,000 vehicles per day. Roots, unwashed foliage and washed foliage of plants were tested separately. Data were evaluated to determine the relationship between root and foliage lead content to plant lifeform (annual or perennial), family (Graminiae, Fabaceae, and Compositae), soil lead, and distance from the highway. No significant differences in lead content of roots were found although the correlation between distance from the highway and root lead was highly significant for all but soybean roots. No effect due to family lifeform was found in lead content of washed foliage. Graminiae had significantly less lead in unwashed foliage than Fabaceae or Compositae; the latter families were not significantly different. Significant species differences were noted in both washed and unwashed samples which showed the same relative relationships. The correlation with distance was significant in foliage of all species and for 10-20 cm soil depth but not for surface soil. Lead in nearly all tissues of all species was highly correlated to soil lead irrespective of distance. Data suggest that species exposed to similar conditions of lead contamination will manifest significant differences in absorbed lead and that both soil and fallout lead serve to contaminate plants.

[1]The authors gratefully acknowledge the guidance of Dr. Arnold Hartley in the analytic procedures. The analytic laboratory was established and supported with help from N.S.F. G.I.-26

Numerous investigators have shown that the concentration of lead in soils and plants is significantly higher near highways and drops rapidly along gradients away from this source (Page et al. 1971, Motto et al. 1970, Ruhling and Tyler 1968, Suchdoller 1967, Martin and Hammond 1966, Kloke et al. 1966, Cannon and Bowles 1962). Although wind direction, speed and turbulence are important factors in determining the steepness of these lead gradients, Suchdoller (1967) reported that the lead gradient in beans and barley may be diminished to background within 30 to 40 meters from a highway.

Little is known at present about the forms of lead in the soil. Hirschler and Gilbert (1964) reported that inorganic lead particulates, in the form of PbCl·Br or ammonium halide-lead halide complexes, are exhausted into the air by automobiles using lead additives in the gasoline. These authors noted that lead halides were the prevalent form of lead from exhausts. Lead use as a gasoline additive in 1969 consumed 271,128 short tons, the second greatest use of lead in the United States (Borcina 1969). With the majority of this lead becoming deposited in narrow corridors along the streets and highways, it is not surprising that problems of lead contamination are developing.

Contamination of vegetation and soils near highways first was examined by Warren and Delavault (1962). Since then, there have been numerous investigations of this nature. Cannon and Bowles (1962) found lead concentrations of 100 to 700 ppm in the ash of grass samples collected on the edge of a major highway in Colorado. The lead content decreased with distance from the highway to a range of less than 5 to 50 ppm in ashed samples collected at distances of 500 to 1000 feet from the highway. Lead concentrations of 3000 ppm were reported in grass samples at the intersection of two heavily traveled highways while samples collected at the intersection of two less-traveled highways contained 300 to 500 ppm. Their conclusions were that the distribution of lead from an automobile source is controlled by two factors; traffic volume and the prevailing wind direction. Warren and Delavault (1962) determined lead in tree boles collected at locations remote from and adjacent to heavily traveled highways. Values for the remote area were 0.4 to 2.0 ppm (in oven-dry tissue) as compared with 2.0 to 50 ppm in the area of heavy traffic.

Motto et al. (1970) reported that lead content of soils and plants sampled along heavily traveled highways increases with traffic volume and decreases with distance from the highway. They also reported that the major effect of traffic was limited to the surface soil in a narrow zone within 100 feet of the road. In greenhouse and field studies, it was noted that plants can obtain lead through both leaves and roots with little translocation within the plant and that fruiting and flowering portions of contaminated plants contain the smallest amounts of lead (Motto et al. 1970).

The relationship of automotive lead particulates to certain consumer crop species was studied by Schuck and Locke (1970). Five crop species were analyzed for lead content as well as the soil, water and air in contact with these crops. Although growing near heavily traveled highways

(up to 50,000 vehicles per day), the amount of lead associated with the five species was never greater than 1 µg of lead per gram of fresh weight. The combined findings suggest that lead is not concentrated in the edible portion of the crop.

Although considerable research has been done concerning relationships between automotive lead particulates and plants or soils, there have been no studies examining the relationship between these lead exposures and contamination of various plant species or families.

The purpose of this study was to verify the expected lead gradient along the major highway selected for study, examine the relationship between total lead in the soil and that on and in plants, and compare lead uptake by annuals and perennials in each of three representative plant families. Species selected for study are given in Table 1.

TABLE 1. Plant species[2] examined for lead contamination

Family	Annual	Perennial
Graminiae	Zea mays (corn)	Poa pratensis (bluegrass)
Fabaceae	Glycine max (soybean)	Melilotus officinalis (yellow sweetclover)
Compositae	Erigeron annuus (fleabane)	Taraxacum officinale (dandelion)

METHODS

The highway selected as the primary site for this study was State Route 45 between Urbana and Rantoul, Illinois. Illinois Division of Highways estimated the traffic volume for this road in 1967 to be 11,400 vehicles with a three percent increase per year. Transects were established primarily to the east (downwind) of the north-south road in fencerows and fields on silt-loam prairie soil. Soil pH ranged from 7.0 to 7.4. Effort was made to avoid forest and transition soils that also are present in the area. Plants of the species listed in Table 1 were carefully dug as they occurred along the transects to at least 200 meters from the edge of the pavement. Corn and soybeans were sampled from agricultural fields whereas the other species were sampled from adjacent fencerows and fallow field populations. Soil was removed from the roots and the plants were placed individually in clean plastic bags for transport to the laboratory. At each plant collection site, two composite soil samples were taken with a clean, stainless steel, soil bucket-auger, one sample at 0-10 cm depth and the second from 10-20 cm depth. Each sample was labeled and the distance from the pavement was recorded. Plant

[2]Nomenclature is that of Gleason and Cronquist (1963).

and soil samples were collected during a four week period from 8 July to 7 August 1969.

In the laboratory, each plant sample was separated into roots, and two foliage subsamples. The roots and one of the foliage subsamples of each sample were washed through deionized water, glass distilled water, and double glass distilled water baths, then rinsed in a double glass distilled water stream. Water baths were changed after each ten samples. Extreme care was taken to avoid contamination in handling or exposure to air. Each subsample was placed in layered paper towels and then in loosely packed plant presses. Presses were covered and placed in a drier powered with six 100 watt bulbs. After plants were dried, samples individually were sealed in new plastic bags. Soils were dried under cover and ground with a porcelain mortar and pestle and sieved through a brass 2 mm sieve. Equipment was scrupulously cleaned after each sample.

Both 100 ml pyrex beakers and 50 ml vycor crucibles were used as sample containers. In all cases the glassware was soaked in 1:1 constant boiling HCl and deionized water before usage to leach out any trace metals. The glassware was similarly treated between uses.

All standard solutions were kept in screw-top polyethylene bottles which were conditioned to the concentration for which they were to be used for approximately one week before use. All atomic absorption measurements were made using a Beckman 440 Atomic Absorption Spectrophotometer with a Beckman Hollow Cathode lamp.

An acid solution was prepared using the constant boiling fraction of an HCl distillation prepared in the laboratory. This fraction (6 M HCl) was diluted 1:1 by weight with deionized water. This solution (3 M HCl) will be referred to as the HCl solution.

Standard solutions were prepared from a 1000 ppm Pb stock solution or from a 100 ppm solution. The stock solution was prepared by dissolving 1.5985 g of reagent grade $Pb(NO_3)$ in enough deionized water to make 1000.00 g of solution. A 100 ppm Pb solution was made by a 1:10 dilution by weight of the stock solution, using deionized water. Standards of 10.0 and 5.0 ppm were prepared by dilutions of the 1000 ppm solution. Standards of 2.5, 1.0 and 0.50 ppm were prepared by dilutions of the 100 ppm solution. Solutions were remade weekly.

Root and foliage samples, weighing between 0.8 g and 3.0 g, were placed in a beaker or crucible and dried in an oven at 105° C for a minimum of two hours. Drying time in excess of two hours was noted to have no further effect on weight loss of samples which had been previously dried after preliminary preparation. The dried samples were weighed on an analytical balance and placed in a muffle furnace at 450° C for a minimum of six hours. (Ashing times greater than six hours were investigated using duplicate samples and resulted in reproducible weight losses on ashing and reproducible concentrations of lead in the final determination.) The ash residues were weighed and the percent weight losses were calculated. The average weight loss for roots and foliage was 95 ± 1 percent, except for grasses (corn and bluegrass) where the loss was found to be 93 ± 2 percent.

Ash residues were treated with 20.00 g of HCl solution and warmed overnight, loosely covered, on a hot plate. The solutions were then brought back to a net weight of 20.00 g by the addition of deionized water. These solutions were analyzed for lead by the method of atomic absorption spectrophotometry.

Instrument parameters used were:

283.3 μm wavelength
20 ma lamp current
650-750 PM voltage
10:1 air to acetylene, usually with 20 lbs support triple pass, using mirrors to provide approximately 30 cm of flame

The 10:1 support to fuel ratio gave a slightly lean flame and was identified as the point at which the hydroxyl bands disappeared.

The concentration of lead in each 20.00 g solution was determined by comparison with a calibration curve of standards which were run on the instrument between each 5 or 6 samples. Soil samples were treated as above except that initial samples ranged in weight from 1 g to about 8 g. The average percent weight loss on ashing was found to be 7 ± 1 percent. No corrections were used for sample preparation losses because samples were checked by recovery. For each set of samples, a matrix factor correction was obtained by standard addition methods. Background was measured frequently during analysis of each batch of samples and was corrected by either reference to the nonresident lead line at 282.0 μm or the neon line at 280.2 μm.

RESULTS

The lead content of surface soils (0-10 cm) showed a nonsignificant ($P \leq 0.072$) negative correlation to the log of the distance from the highway (Fig. 1). The correlation between soil lead and distance accounted for 5.25 percent of the variance in the data. The correlation between the log of the distance from the highway and lead content of subsurface soil (10-20 cm) was significant ($P \leq 0.025$) but accounted for only 2.17 percent of the variance in observed lead content. The correlation between surface and subsurface soil lead also was significant ($P \leq 0.001$) and accounted for 50.4 percent of the variance (Fig. 2).

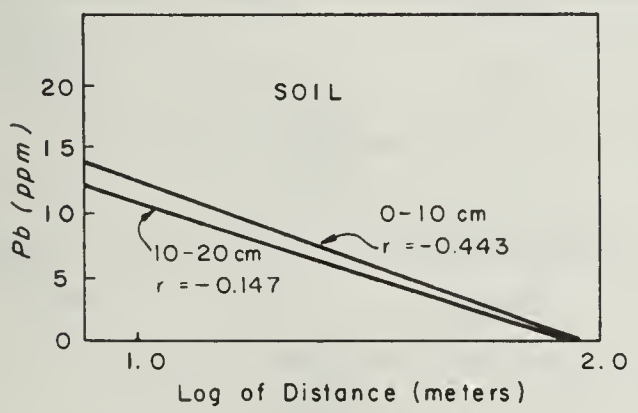

Figure 1. Relationship between soil lead and distance from highway.

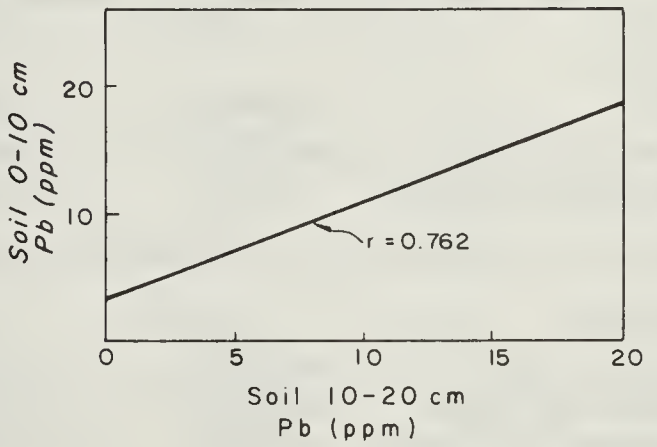

Figure 2. Relationship between surface-soil lead and subsoil (10-20 cm) lead for transect shown in Figure 1.

In nearly all species tested, lead in and/or on tissues was a function both of distance from the road and lead in the soil. Correlations with distance are summarized in Table 2 and with soil lead in Table 3. Lead content of all tissues examined, except soybean root, significantly was correlated to the log of the distance from the highway although the percent of the variance accounted for by the correlation often was very small.

TABLE 2. Summary of correlations between log of distance from highway and lead in plants. Probabilities are based on a "Z" distribution.

	Correlation coefficient	Significance ($P \leq$)	Percent of variance accounted for by correlation
Corn			
root	-0.417	0.0014	17.4
washed foliage	-0.657	0.0000	43.1
unwashed foliage	-0.612	0.0000	37.5
Bluegrass			
root	-0.424	0.0154	18.0
washed foliage	-0.674	0.0005	45.5
unwashed foliage	-0.793	0.0000	63.0
Soybean			
root	-0.094	0.2546	0.9
washed foliage	-0.727	0.0000	52.9
unwashed foliage	-0.681	0.0000	46.4
Sweetclover			
root	-0.392	0.0051	15.4
washed foliage	-0.640	0.0000	41.0
unwashed foliage	-0.668	0.0000	44.7
Fleabane			
root	-0.412	0.0020	17.0
washed foliage	-0.770	0.0000	59.4
unwashed foliage	-0.722	0.0000	52.2
Dandelion			
root	-0.591	0.0089	35.0
washed foliage	-0.638	0.0054	40.8
unwashed foliage	-0.792	0.0015	62.8

TABLE 3. Summary of correlations between lead in soil and lead in plants. Probabilities are based on a "Z" distribution.

	Surface Soil (0-10 cm)			Subsurface Soil (10-20 cm)		
	Correlation coefficient	Significance (P ≤)	Percent of variance	Correlation coefficient	Significance (P ≤)	Percent of variance
Corn						
root	0.723	0.0000	52.3	0.449	0.0010	20.1
washed foliage	0.169	0.1335	2.9	0.370	0.0060	13.7
Bluegrass						
root	0.421	0.1335	17.7	-0.119	0.3520	1.4
washed foliage	0.680	0.0359	46.3	-0.161	0.3050	2.6
Soybean						
root	0.305	0.0217	9.3	0.324	0.0150	10.5
washed foliage	0.373	0.0136	13.9	0.432	0.0043	18.7
Sweetclover						
root	0.035	0.4325	0.1	0.170	0.2119	2.9
washed foliage	0.248	0.1112	6.2	0.112	0.3015	1.2
Fleabane						
root	0.170	0.1539	2.9	0.383	0.0139	14.7
washed foliage	0.322	0.0301	10.4	0.288	0.0548	8.3
Dandelion						
root	0.367	0.1112	13.5	-0.077	0.3974	0.6
washed foliage	0.641	0.0166	41.1	-0.170	0.2877	2.9

Lead in corn and soybean roots, and that in bluegrass, soybean, fleabane and dandelion foliage was significantly correlated to lead content of surface soil (0-10 cm). Lead in roots of corn, soybean and fleabane were significantly correlated to subsurface soil lead (10-20 cm); lead in foliage of corn and

soybeans were similarly correlated. Variances accounted for by these correlations were small. Within every sampled population, variance was high, suggesting either extreme fluctuation of lead content within the gradient from the highway and lack of consistent association between soil lead and plant uptake, or experimental error.

Figures 3 through 8 show the relationship between soil lead and plant tissue lead. Note that only grass (corn and bluegrass) shows a strong positive relation suggesting that soil lead may be the primary source of lead in tissues of these species.

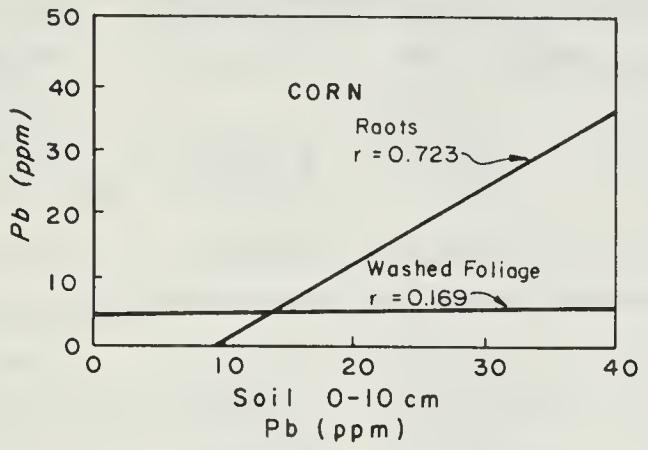

Figure 3. Relationship between soil lead and lead in foliage and roots of corn at time of tasseling.

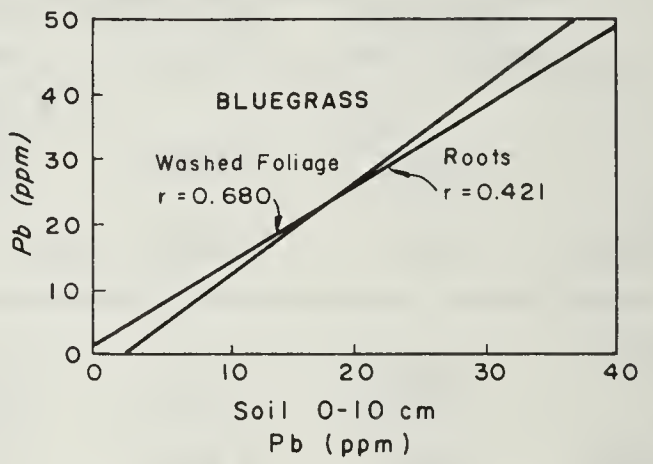

Figure 4. Lead in foliage and roots of bluegrass as related to soil lead.

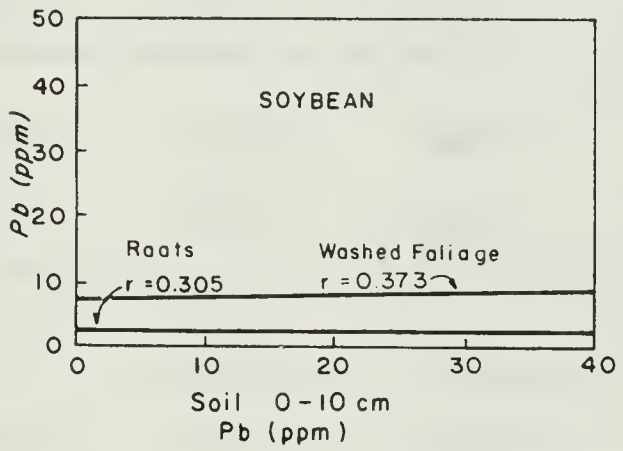

Figure 5. Relationship of lead in soybean roots and foliage as a function of soil lead.

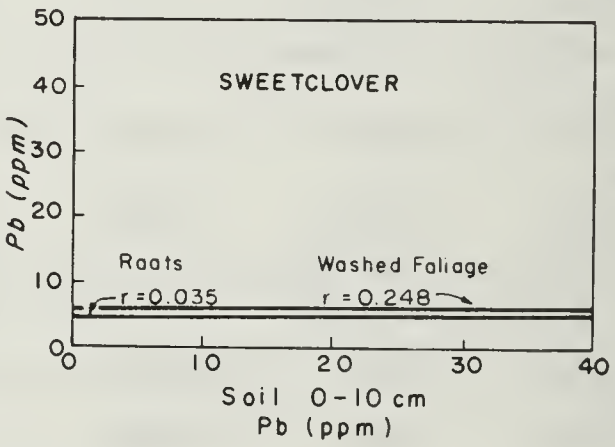

Figure 6. Relationship of lead in sweetclover roots and foliage as a function of soil lead.

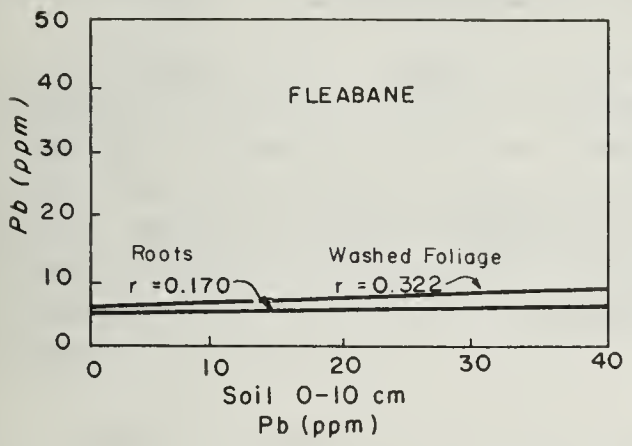

Figure 7. Lead in foliage and roots of fleabane as related to soil lead.

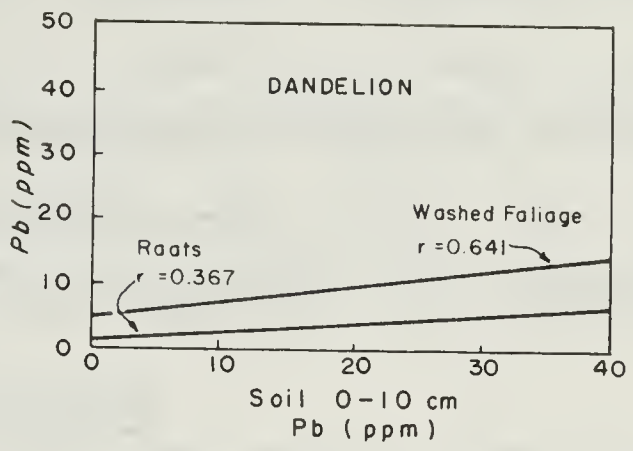

Figure 8. Relationship of lead in dandelion roots and foliage as a function of soil lead.

Analyses of variance were run to determine if there were significant differences ($P \leq 0.05$) in lead content of families (3) or lifeforms (2) (i.e., annual or perennial); lifeform-family interactions were tested and variance attributed to distance was isolated. No significant differences were found in root lead. With washed foliage, the lifeform-family interaction was significant. Table 4 shows the interpretation of the significant interaction.

TABLE 4. Analysis of significant lifeform-family interaction of lead in washed foliage using Tukey's w-procedure at $P \leq 0.05$. Values are mean lead levels in ppm. A common underline indicates no significant difference.

Soybean	Dandelion	Bluegrass	Fleabane	Sweetclover	Corn
11.4	9.6	8.6	6.8	6.0	6.0

A similar analysis of variance for lead content of unwashed foliage showed significant differences between families as well as lifeform-family interaction. Interpretation of the interaction is given in Table 5.

TABLE 5. Analysis of significant lifeform-family interaction of lead in unwashed foliage using Tukey's w-procedure at $P \leq 0.05$. Values are mean lead levels in ppm. A common underline indicates no significant differences.

Soybean	Dandelion	Bluegrass	Fleabane	Sweetclover	Corn
14.7	14.0	10.7	8.9	6.7	6.5

DISCUSSION

As noted in the results, a significant correlation routinely was found between lead in soil, lead in and/or on plants, and the log of the distance from the highway. This confirms the conclusion of all earlier workers, cited above. Correlation coefficients, however, or percent of variance accounted for by the correlation, generally was small, indicating a great amount of variance in the data of a species or soil that was unrelated to distance. Much of this variance undoubtedly was real, indicating much irregularity in the distribution of lead in the field. Experimental error, resulting from accidental contamination of samples during collecting and processing, and analytical error certainly contributed some of the variance. Careful control of the analytical procedures allows us to assume an accuracy of at least one part per million. Likewise, field methods and processing of samples were applied with extreme care to avoid contamination. Therefore, we assume that most of the variance observed was not introduced by experimental error. The high amount of variation in the distribution of lead along highway gradients greatly reduces the predictive ability of models for lead distribution in the environment. Our data suggest that lead in soil can be predicted from information on traffic and distance from source with less than 50 percent accuracy.

Given only a known content of lead in soil, our data further suggest that only a poor prediction can be made of lead in plants growing in the soil. This prediction is only slightly improved by noting the species or lifeform of the plant. In general, it appears that the rate plants absorb lead is a function of much more than lead content of the soil and the species.

As indicated in the data in Table 3, lead in the surface soil (0-10 cm) was much better correlated to plant tissue lead levels than subsurface soil (10-20 cm) lead. This was true for "weedy" species, often growing in irregularly tilled soil, and for crop species where tillage mixes lead deposited on the surface into the plow layer. Apparently, roots in the top 10 cm of the soil are much more important in lead uptake than roots at 10 to 20 cm. One possible interpretation of these data that seems justified is that some significant translocation does occur from roots to foliage, in

at least some species, bluegrass and soybeans, for example. This is in contrast to the summary of Motto et al. (1970). Although there were no significant differences in root lead among the species tested, corn root lead was much more highly correlated to soil lead than was lead in roots of other species. Similarly, lead in bluegrass and dandelion foliage was better correlated to soil lead, although the average content of lead in foliage of these species apparently was not as great as that in soybeans.

Lead in many species showed a higher correlation to distance from the highway than to actual soil lead. This is not unexpected with lead from unwashed tissue where leaf surface contamination is important, but was not expected in washed tissues, especially roots. This suggests that experimental error in soil analyses was compounded by experimental error in plant tissue analysis resulting in lower correlation between these parameters than between tissue lead and distance which was relatively free of experimental error.

Data in Tables 4 and 5 suggests either that surface contamination of plants by lead is relatively small or that our techniques were inefficient for removing lead. Probably both interpretations apply. It is apparent from the data that washing did remove some lead (Table 6). Because the

TABLE 6. Lead removed from plant foliage by two washings and double distilled water for the final rinse. Data are mean lead levels of all samples.

Species	Unwashed foliage	Washed foliage	Difference	Percent
Soybean	14.7	11.4	3.3	23
Dandelion	14.0	9.6	4.4	31
Bluegrass	10.7	8.6	2.1	19
Fleabane	8.9	6.8	2.1	24
Sweetclover	6.7	6.0	0.7	10
Corn	6.5	6.0	0.5	8

amount of lead removed by washing, as indicated in Table 6, did show a trend parallel to the amount present in the unwashed samples, one must reserve judgment on the significance of lead in plant tissue based on washed samples. Washing tended to reduce differences between species and, perhaps, more thorough washing would eliminate significant differences. Thus, soybeans may appear to absorb more lead merely because the pubescent leaves are more difficult to wash. On the other hand, dandelion probably did have more lead than sweetclover or corn, all of which have relatively smooth surfaces that are washed easily. Recall that roots, which are much more comparable in texture, showed no significant differences between species.

All species examined tended to have less lead in roots than in washed foliage throughout the 200 m gradient from the highway. Plants within 30 m of the highway had, on the average, about twice as much lead in roots and three times as much lead in foliage as plants 100 m or more away from the

highway. Beyond 100 m downwind there was no apparent trend in lead level, a conclusion that confirms the reports by Suchdoller (1967) and Motto et al. (1970).

Additional studies are underway to determine factors influencing lead absorption from soil by plants. We expect from our data that species differences in lead uptake occur, yet unknown environmental factors apparently influence lead uptake beyond species differences. Because our study was conducted on the same soil type within a relatively small area, physical characteristics of soil were quite similar. Therefore, we believe that chemical characteristics of soils, such as pH and phosphorus level, may be more important in determining the rate of uptake by plants than texture or structure.

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FAUNAL REMAINS FROM A LEWIS FOCUS STONE FORT IN SOUTHERN ILLINOIS

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Abstract. The Hog Bluff Site, a Lewis Focus Late Woodland archaeological site in southern Illinois, has provided the first opportunity to study the animal remains from a southern Illinois Late Woodland stone fort. Nearly a thousand remains of mammals, birds, reptiles, and mussels representing 28 individuals reveal that the forest surrounding the site was the principal resource area exploited.

The significance of "stone forts" in Southern Illinois and their relationship to other stone walled sites in Eastern North America is not understood. To gain insight into this problem, the Hog Bluff site, a "stone fort" located in Johnson Co., Illinois, was excavated in the summer of 1973 by the University Museum, Southern Illinois University at Carbondale. This site was occupied between AD 600 and AD 1200 during the Lewis focus of the Late Woodland period (Brieschke 1973:20).

Previously excavated "stone forts" lack faunal data due to poor bone preservation and a lack of awareness of its possible importance. The faunal materials from the Hog Bluff site are well preserved and offer an additional means for understanding its inhabitants and their relationship to the Eastern North American Late Woodland period.

RESULTS

The faunal material from the Hog Bluff site is from a single unstratified midden which contained 939 skeletal fragments. Mammals, birds, reptiles and mussels are represented; however, neither amphibian nor fish remains were present. The number of identifiable bone fragments, the minimum number of animals represented, and their percentages are given in Table 1.

Mammals

Remains of eight species of mammals occurred at the site. The white-tailed deer supplied the greatest amount of meat to the Hog Bluff people. No deer mandibles were complete enough to be aged though at least one individual was immature as evidenced by the presence of a deciduous maxillary molar and the incomplete fusion of the epiphysis and diaphysis of one ulna. Nearly all deer skeletal elements are represented which suggests that the entire animal was brought back to the camp. The long bones are fragmented indicating the extraction of marrow. Butchering and skinning marks as defined by Guilday,et al.

TABLE 1. Animals from the Hog Bluff Site.

Animals	Total Identified	Minimum Number	Percent of Total Minimum Number
MAMMALS	722	11	39.27
Odocoileus virginianus (Zimmerman) White-tailed deer	107	3	10.71
Procyon lotor (Linnaeus) Raccoon	5	2	7.14
Castor canadensis Kuhl Beaver	2	1	3.57
Urocyon cinereoargenteus (Schreber) Gray fox	2	1	3.57
Scalopus aquaticus (Linnaeus) Eastern mole	2	1	3.57
Mephitis mephitis (Schreber) Striped skunk	1	1	3.57
Sciurus carolinensis Gmelin Eastern gray squirrel	1	1	3.57
Sylvilagus sp. Gray Rabbit	1	1	3.57
Indeterminate mammals	601	-	-
Indeterminate bird or mammal	26	-	-
BIRDS	35	4	14.28
Meleagris gallopavo Linnaeus Turkey	5	1	3.57
Tympanuchus cupido (Linnaeus) Prairie chicken	2	1	3.57
Bonasa umbellus (Linnaeus) Ruffed grouse	1	1	3.57
Dryocopus pileatus (Linnaeus) Pileated Woodpecker	1	1	3.57
Indeterminate birds	26	-	-
REPTILES	120	9	32.14
Terrapene sp. Box turtle	46	3	10.71
Tarrapene caroline (Linnaeus) Eastern box turtle	1	1	3.57
Pseudemys-Graptemys-Chrysemys	4	1	3.57
Sternothaerus odoratus (Latreille) Stinkpot	1	1	3.57
Indeterminate turtle	59	-	-
Crotalus sp. cf. *C. horridus* Linnaeus Timber rattlesnake	2	1	3.57
Natrix sp. Watersnake	1	1	3.57
Colubrinae	1	1	3.57
Indeterminate snake vertebrae	5	-	-

MUSSELS	36	4	14.28
Megalonaias gigantea Washboard	2	1	3.57
Megalonaias gigantea (Barnes)	2	1	3.57
Amblema plicata (Lamarck) Washboard or Three ridge			
Anodonta grandis Say Floater	1	1	3.57
Lampsilis sp.	1	1	3.57
Indeterminate mussels	30	-	-
Total number	939	28	99.97

(1962:63-64) appear on the anterior border of one scapula and below the proximal head of a metacarpal. Deer bone artifacts consist of one proximal phlange modified by the removal of its proximal and distal ends. Artifacts of this type are described by Guilday (1963) as being cup and pin games. Two deer ulna shafts were modified into what appear to be awls. Skinning marks appear on a raccoon maxilla between the jugal bone and the second molar and on the ventral labial portion of a beaver mandible. Skinning marks on the raccoon and beaver resulted from the separation of the pelt from the head. All mammals recovered are found in forest and forest edge habitats.

Birds

The prairie chicken is the only animal represented in the faunal assemblage that is restricted to a prairie/bushy grassland habitat. The pileated woodpecker, turkey, and ruffed grouse are associated with forest habitats. One turkey tarsometarsus was modified into an awl.

Reptiles

No modifications appear on either the identifiable or unidentifiable turtle bones. The one box turtle plastron from which sex could be determined is a male. It is a matter of speculation whether the snake remains resulted from direct food gathering activities or if their presence occurred independent of human agency. The eastern box turtle and timber rattlesnake are restricted to wooded areas while *Natrix* sp., *Sternothaerus odoratus*, and *Pseudemys-Graptemys-Chrysemys* group are aquatic reptiles.

Mussels

Anodonta grandis, *Megalonaias gigantea*, and *Amblema plicata*, presently found in rivers and streams near the site, probably were collected from the Ohio River. Differential preservation may have decreased the number of recoverable mussel shell remains since shells are rapidly eroded if soil conditions become acidic. However, the distance of the site from the Ohio River would make mussels less desirable as a food source, thus reducing the number in the remains. One mussel fragment was cut or sawed from the ventral margin approximately two millimeters inward. The function of this artifact is unknown.

DISCUSSION

The faunal material from the Hog Bluff site contained a limited number of mammal, bird, reptile, and mussel remains. Mammals comprised the largest group with deer being the most valuable animal food resource. Various other animals subsidized the diet.

Exploitation of animals was based primarily around forest and forest edge habitats, the animals from these habitats comprising at least 65 percent of the total minimum number. Only the prairie chicken is restricted to a prairie/bushy grassland. The lack of fish remains and the restricted number of mussels, amphibians, and aquatic reptiles indicates that the exploitation of aquatic resources was minimal. This is probably due to the distance of the site from the Ohio River.

The present day ranges of all species recovered from the midden, except

the prairie chicken and ruffed grouse, include the area of the site. Evidences from bone remains found in other archaeological sites in the Midwest indicate that the prehistoric range of the prairie chicken was much more extensive than it is presently. It is likely that during occupation of the stone fort this bird was found near the site in small prairie areas. Although probably presently extirpated in the area of the Hog Bluff Site, the ruffed grouse was prehistorically more than likely a common bird around the site.

ACKNOWLEDGMENTS

We wish to express our thanks to Dr. Walter Brieschke and Mr. Frank Rackerby of Southern Illinois University, Carbondale for allowing us to study the Hog Bluff animal remains and for supplying information concerning the archaeology of the site. We are indebted to Dr. Paul W. Parmalee of the Illinois State Museum who has again graciously aided in identification of certain bird materials. We also wish to express thanks to Mr. David White of the University of Louisville for his critical reading of the final manuscript.

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DDT AND METHOXYCHLOR IN A FROG POPULATION IN COOK COUNTY

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ABSTRACT

Qualitative thin layer chromatographic techniques were used for determination of DDT and Methoxychlor in the fat bodies of 61 frogs. Fifty-nine of the frogs were positive for the insecticides.

The purpose of this study was to obtain qualitative data on the presence of DDT in frogs in an aquatic habitat in Cook County. The time period of the research (May through September of 1969), was concurrent with a change-over of pesticides used in the Cook County Forest Preserve District's Mosquito Abatement Program. The spraying schedule was as follows: DDT was sprayed in the Fall and Methoxychlor in the Spring. The schedule was to be changed to Methoxychlor only in both sprayings in 1970.

The area selected for the study was Saganashkee Slough, in southwest Cook County. This Slough is large and deep and supports a large population of aquatic animals including frogs, turtles, bluegills, bass, crappies, sunfish, and shiners. Several water-loving land animals such as raccoons, woodchucks and muskrats are in the area. Saganashkee Slough is surrounded by a dense deciduous forest. The location of the Slough is shown in Figure 1.

The animals selected for study were frogs, since they are at the top of one food chain involving mosquitoes and other insects; they are readily captured compared to the bass in the Slough, which are at the top of a food chain involving the mosquitoes and other insects, shiners and tadpoles. Frog fat bodies are conveniently removed for analysis of DDT and other chlorinated hydrocarbons.

MATERIALS AND METHODS

The method of extraction was taken from that of Mills (1959) with changes as follows:

The fat to be tested was removed from the frog and melted over a hotwater bath. This is necessary to prevent scorching of the small quantity that will be taken. After the fat is melted, it is dissolved in petroleum ether (bp 61-110^{o}C), and extracted four times with 25 ml volumes of acetonitrile. The acetonitrile was extracted with diethyl ether, washed with distilled

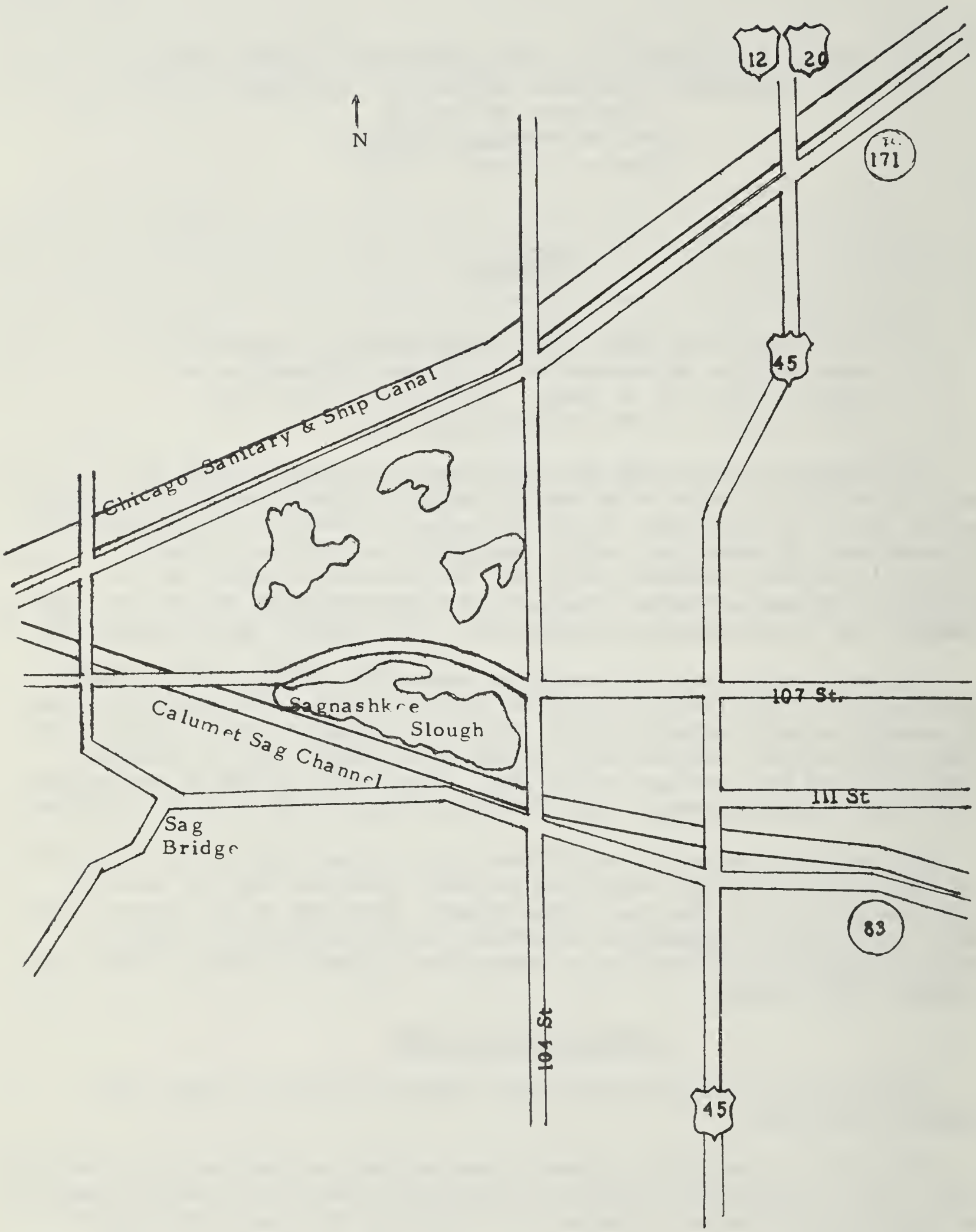

Figure 1. Location of Sagnashkee Slough, Cook County, Illinois.

water, dried through a column of anhydrous sodium sulfate and condensed by open air evaporation to a volume of 35 ml. After cleanup in a chromatographic column of 60-100 mesh activated with Florisil, the eluant was air dried and picked up in a cyclohexane-chloroform carrier (Mills, 1959).

Thin layer chromatography was done using Gelman ITLC sheets prepared with ethylamine (Stahl 1965) and detection was done using HNO_3 and $AgNO_3$ followed by exposure to u.v. light for 10 seconds.

Positive results showed a yellow ring from nitration of the phenyl of DDT and Methoxychlor and their respective breakdown products. DDD and DDE do not exist in most commercial preparations of the DDT (Haller, 1945), but are breakdown products. DDD (222-bis-(p-ethylphenyl-)-1,1-dichloroethane) is also sold under the trade name Perthane, but was not used by the Cook County Forest Preserve District. DDD is considerably less abundant than DDT in fat storage (Metcalf, 1955) in rats. The most likely source of DDD in this experiment would be as a breakdown product of DDT. Other pesticides which could be detected using this technique are the pyridine-based pesticides which were not used in the immediate area. There are no major agricultural areas in this area to provide an immediate source of other pesticides, although (Cory, 1968) reported wind borne pesticides can be found in areas where there is no spraying.

RESULTS

Concentrations of the pesticides were found in 59 of the 61 frogs tested. Two male Rana clamitans melanata were negative for insecticide. The fat bodies of all animals were examined except one, which had none. Results are shown in Table 1.

TABLE 1. Incidence of DDT and Methoxychlor in a frog population from Sagnashkee Slough.

SPECIES	NO. MALES	NO. FEMALES	NEGATIVE	.799-.817 POSITIVE DDT		.819-.837 POSITIVE METHOXYCHLOR	
			M	F	M	F	M
Rana clamitans melanata	44	7	2	6	23	5	22
Rana catesbiana	1	3		3	1	1	1
Rana pipiens pipiens	4	2		0	3	2	4

In addition to tests on the fat bodies, tests run on the brain and nerve cord, including sciatic and brachial nerves of six male R. clamitans melanata showed positive results in five. The oviducts of all nine females were run through the procedure, with only one from a Rana catesbiana giving positive results.

DISCUSSION

The discovery that virtually the entire sampled population of frogs had pesticide residues in their bodies was not unexpected. The fact that

36 animals contained DDT even though the last DDT spraying had been in October of 1968 is further evidence of the longevity of this pesticide. This longevity was one strong reason for the banning of the use of DDT in this country, and for the substitution of Methoxychlor, a "soft" pesticide, by the Cook County Forest Preserve District (S. Gabriel, Chief Forester, Cook County Forest Preserve District, personal communication). This study shows that this pesticide also rapidly enters the environment with 35 animals positive for Methoxychlor. With two sprayings annually, it can be considered to be as permanent as the DDT it replaced, unless it can be shown to be specific enough that it will not harm other organisms in the environment in the applied and residual concentrations.

SUMMARY

A qualitative determination for DDT and Methoxychlor was successful using thin layer chromatographic techniques. Of 61 animals tested, 59 tested positive for DDT and/or Methoxychlor residues. Tests run with controls of tripalmitin (four runs) and tristerin (eight runs) showed no similarity to chromatographs made with control extracts.

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THE INFLUENCE OF CARBON SOURCES ON PIGMENTS PRODUCED BY PSEUDOMONAS AERUGINOSA

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ABSTRACT: Conditions and media for production of red and crystalline pigments by Pseudomonas aeruginosa were described. With these methods 57.3% of 199 cultures formed a red pigment and 56.6% of 122 cultures formed crystalline pigments. The cultures were all capable of producing pyocyanin. Variation of the carbon source in minimal salts medium caused considerable differences in the pigments produced.

Production of water soluble, diffusible pigments is a characteristic used in the identification of the various pseudomonads. Pyocyanin, the blue, water-soluble phenazine pigment is characteristic of Pseudomonas aeruginosa. Red water-soluble pigments are also formed by P. aeruginosa (Meader et al., 1925; Holliman, 1957 and Labeyrie et al., 1968), however, there is no information as to the number of isolates capable of forming a red pigment. A few strains of P. aeruginosa were shown to produce crystalline pigments (Haynes and Rhodes, 1962; Chang and Blackwood, 1968), which are characteristics of P. chlororaphis (Haynes and Rhodes, 1962) and P. aureofaciens (Haynes et al., 1956). The present study shows how the carbon source influences the formation of pigments by isolates of P. aeruginosa which are also capable of producing pyocyanin.

MATERIALS AND METHODS

Cultures of P. aeruginosa were isolated from a variety of pathological and non-pathological sources and identified by methods described by Wahba and Darrell (1965). All cultures were examined with the pyocin typing method of Kocka and Harris (1973). This procedure by definition had diagnostic value as well as indicating a difference among strains. Strains of P. aeruginosa capable of forming oxychlororaphin and P. aureofaciens cultures that produced phenazine-1-carboxylic acid were obtained from W. C. Haynes (Northern Regional Research and Development Division, Peoria, Illinois 61604, USA). Cultures were incubated at 30°C unless otherwise noted.

The defined mineral salts base contained: 14.4 g K_2HPO_4, 5.6 g KH_2PO_4, 1.6 g $MgSO_4.7H_2O$, 1.6 g NaCl, 1.6 ml of 10% $CaCl_2$, 1.6 ml 10% $FeCl_3$ and 4 liters of distilled water. Before the medium was autoclaved, 0.5% $(NH_4)_2SO_4$ and the carbon source were added. The carbon source was either 0.2% (w/v) or 2.0% (w/v) as noted. The pH was then adjusted to 6.8. When a solid medium was desired, 1.0% Ionagar 2S (Wilson Diagnostics, Inc., Glenwood, Illinois USA) was used.

Sierra's medium (Sierra, 1957) and Gessard's medium (Harris, 1950) were used to demonstrate pyocyanin formation. Pyocyanin was extracted from the culture medium with chloroform. When acidified the pyocyanin moved to the aqueous layer and turned this layer red. This test has been considered presumptive for pyocyanin (Young, 1947).

RESULTS

During the process of screening P. aeruginosa cultures for the ability to utilize glycine as a sole carbon and energy source, a red pigment was formed by a majority of the isolates (Table 1). This pigment was produced after 5 to 7 days growth on 0.2% (w/v) glycine-mineral salts agar at 30°C. When grown in glycine-mineral salts liquid culture with slow shaking, the maximum amount of pigment was formed after

6 days growth at 30°C. Just prior to the maximum pigments production, the population started to decline, and the pH reached its highest value of 8.1. Some cultures that made pyocyanin on the glycine-mineral salts medium also produced the red pigment (Table 2). Pyocyanin was generally formed after 2 days growth at 30°C and masked the red pigment which was formed at a later time. The red pigment was seen after extracting the pyocyanin from the medium with chloroform.

Alanine, glutamate or asparagine as sole carbon sources also supported the formation of the red pigment, but other pigments also formed obscured its appearance.

When 0.2% glycerol and 0.2% glycylglycine together replaced glycine in the mineral salts agar as the carbon source, the cultures first turned yellow. Then occasionally the iridescent material and a red water-soluble pigment were formed. After 5 to 7 days at 30°C, two crystal types were present in the subsurface growth of many cultures. Large ray-like crystals, sometimes several mm long were yellow or yellow-green. Application of 1% sodium dithionite to the surface growth caused the crystals to be reduced to a dark green color. The second crystal type was irregular in shape and generally smaller than 1 mm in its largest dimension. These crystals were yellow to orange in color and turned brilliant orange when treated with sodium dithionite solution. The strains of P. aeruginosa capable of producing oxchlororaphin formed crystals similar to the large form and P. aureofaciens formed crystals identical in appearance to the smaller form. Both reacted in the expected manner to sodium dithionite solution.

The glycylglycine-glycerol medium was found to be the most consistent medium for the production of these crystals. Crystals were also formed by some strains with leucyglycine-glycerol, glycylserine-glycerol and glycine-glycerol as a carbon source. The organisms required ammonium sulfate or a nitrogen source for crystal production, however, the organisms were capable of growing with only the amino acid as the nitrogen

source. The most favorable temperature for crystal formation was 30°C. Crystals were seldom formed at 37°C although, growth was luxuriant.

In liquid culture of glycylglycine-glycerol at 30°C, the pH of the medium went to 6.5 in a one week period. Crystals were generally seen 6 to 10 days after inoculation at 30°C. Aeration hindered the formation of crystals.

Of 122 strains of P. aeruginosa examined on the glycylglycine-glycerol medium, 8 strains produced both crystalline pigments simultaneously, 25 produced only the large type crystal, 36 produced only the small type crystal and 53 did not form crystals on this medium. Each strain was tested several times on the medium and consistent results were obtained. No pyocyanin was formed by any culture on this synthetic medium although all did so on the more complex Sierra or Gessard media. When the glycerol content of the medium below 0.1% the red water-soluble pigment was formed in place of the crystals.

DISCUSSION

We have presented evidence that pigments other than pyocyanin are commonly formed by many strains of P. aeruginosa. The probable reasons these pigments were not commonly seen are because they were not formed on routine laboratory media, they were masked by pyocyanin, the cultures were incubated at too high temperatures or not-incubated long enough.

Pyocyanin was generally formed when alanine, glutamate or pyruvate was used as a sole carbon source. However, the crystalline pigments were not formed by P. aeruginosa with these carbon sources which corresponds with the data obtained by Korth (1973) for P. aureofaciens and P. chlororaphis. This shows a difference in metabolism of the phenazine pigments by P. aeruginosa.

Haynes and Rhodes (1962) reported that they unable to devise a medium that supported consistent production of crystals from P. aeruginosa. The glycylglycine-glycerol medium did support repeatable crystalline pigment production by over 50% of all isolates.

This data indicated that crystalline production should not be considered unique to P. chlororaphis and P. aureofaciens.

The red pigment was not chemically characterized in this study; however, the medium used for its production was similar to that used for the production of the aeruginosins (Holliman, 1969) with the exception of leucine and mannitol. Addition of these substances to our medium caused pyocyanin production by our cultures.

TABLE 1 Production of pigment on glycine mineral salts agar by *Pseudomonas aeruginosa*

	PIGMENT PRODUCED			
Culture growing on glycine	red	pyocyanin	brown	none
199	114	25	1	59
%100	57.3	12.6	0.5	29.6

TABLE 2 The effect of carbon sources on the production of the iridescent material and pigments by selected strains of Pseudomonas aeruginosa.

CARBON SOURCE [a]	STRAIN [b]					
	5	12	19	43	54	P17
glucose	I	-	-	-	-	-
glycerol	I	-	-	-	-	-
glycine	R	-	R	R	PR	P
alanine	PR	PRI	PR	PR	P	PRI
acetate	P	I	I	P	I	I
asparagine	PR	I	PI	P	PRI	I
pyruvate	P	I	I	P	PI	I
glutamate	P	I	PI	PR	PI	I
malate	P	-	-	P	P	-
citrate	-	-	-	P	-	-
1% glycerol	I	I	-	-	I	I
tryptophan	-	-	-	-	-	-
tryptophan-glycerol	I	I	I	-	I	I
anthranilate	I	I	I	P	PI	I
glycylglycine-glycerol	IC	IC	IRC	RC	IRC	IC
nutrient agar	P	I	PI	P	I	PI
Sierra's agar	P	P	P	P	P	P

a. All carbon sources were 0.2% unless noted in mineral salts agar. Cultures were held at 30°C for 14 days.

b. R represents red pigment; P- pyocyanin; I-iridescent material; C- crystalline pigment and - no pigment.

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PLANT INVESTIGATIONS VII. THE CONVERSION OF 2-^{14}C-MEVALONIC ACID TO SMILAGENIN IN AGAVE LECHEGUILLA

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Abstract.--The biosynthesis of smilagenin from mevalonic acid in Agave lecheguilla was demonstrated by the formation of labelled smilagenin from 2-^{14}C-mevalonic acid. The isolated radioactive smilagenin was purified by paper and thin layer chromatography, diluted with nonradioactive purified smilagenin, and then recrystallized to constant specific activity. Establishment of radiochemical purity was accomplished by converting the smilagenin to smilagenin acetate and smilagenone. These transformations indicated the smilagenin to be about 75% pure.

Since the initial experiments by Heftmann and workers (1961, 1963) demonstrating the conversion of labelled acetate into diosgenin by Dioscorea floribunda and labelled mevalonic acid into diosgenin, yamogenin, gentrogenin, and correlogenin by Dioscorea spiculiflora, information about the biosynthesis of steroidal sapogenins has been steadily accumulating over the years. For example, cholesterol has been implicated as an obligatory intermediate because of the transformation of 4-^{14}C-cholesterol to diosgenin and kryptogenin in Dioscorea spiculiflora (Bennett and Heftmann, 1965); to tigogenin, diosgenin, and gitogenin in Digitalis lanata (Tschesche and Hulpke, 1965); to neotigogenin in Lycopersicum pimpinellifolium (Bennett et al., 1967); to an open spiroketal glucoside of diosgenin (Joly et al., 1969); and to diosgenin, yonogenin, and tokorogenin in Dioscorea tokoro (Tomita and Uomori, 1971). The application of 25-^{3}H-cholesterol to Dioscorea floribunda and subsequent isolation of 25-^{3}H-diosgenin presents further evidence for a cholesterol intermediate as well as important information about the participation of C-25 in later steps (Joly et al., 1969a). Perhaps, most significant among the experiments conducted during this period was an examination of the radioactive carbon distribution in tigogenin biosynthesized from 2-^{14}C-mevalonate and 3-^{14}C-mevalonate by Digitalis lanata (Joly and Tamm, 1967).

Further information about the biosynthetic pathway for sapogenins includes the determination that neither 22-oxo- nor 22-hydroxycholesterol was incorporated into a steroidal sapogenin by Digitalis lanata (Tschesche et al., 1968) but that 16β, 26-dihydroxycholesterol (Tschesche and Fritz, 1970) and 16β-hydroxycholesterol (Tschesche and Lunert, 1973) were changed to tigogenin and gitogenin in the same plant and that 26-hydroxycholesterol (Bennett et al., 1970) is a precursor of diosgenin in Dioscorea floribunda. It has also been demonstrated that cholestanol and cholestanone but not coprostanol were used by Digitalis lanata to form tigogenin and gitogenin (Tschesche et al., 1970). More recently, 5α-furostane-3β, 26-diol, a rather advanced biosynthetic intermediate,

was shown to be converted to tigogenin in Digitalis lanata (Canonica et al., 1972).

Our program in steroidal sapogenin biosynthesis focused upon the 5β-series and, in particular, upon smilagenin and sarsasapogenin for little is known about the pathways and interconversions involved between these two related sapogenins. We began our studies by examining the incorporation of labelled mevalonic acid into smilagenin by Agave lecheguilla, a plant which is a good source of smilagenin (Wall et al., 1962) and which has been examined for its commercial potential (Printy et al., 1965; Nord, 1959). The only studies with this genus, thus far, has involved mevalonic acid phosphorylation in A. americana (Garcia-Peregin et al., 1972).

EXPERIMENTAL

Application of Mevalonic Acid. Actively growing leaves of Agave lecheguilla were inoculated with an aqueous solution of 2-^{14}C-mevalonic acid (100 μ Ci) by means of a hypodermic syringe. The pores left by the needle were sealed with wax, and the plant was left with daily waterings in a Percival Model E-54U growth chamber maintained at 80-90° F during a 14 hr daylight period and at 65° F during a 10 hr night period. Periodic examination of the plant with a Geiger counter revealed the radioactive material became distributed throughout the plant but was concentrated at the base of the leaves.

Extraction Procedure. After 21 days the plant was processed similar to a procedure by Wall and associates (1952). The whole plant (314 g) was harvested, washed, and homogenized in a Waring blender. The pulverized material was transferred to a flask, enough 95% ethanol added to cover the material, and the mixture refluxed for 45 min. with constant stirring. The solvent was decanted, and the procedure repeated twice more. The alcohol extracts were then combined and concentrated in vacuo until the mixture was mainly water. The material which precipitated was removed by filtration and washed with alcohol. A 4 hr. liquid-liquid extraction of the filtrate with benzene which had been saturated with aqueous alcohol was used to remove the lipids and fats. The benzene extract was washed once with 50% aq. alcohol, then evaporated in vacuo. The residue was then dissolved in 25 ml of benzene and counted. (See Table 1).

The combined aqueous alcohol solutions were adjusted to pH 4.5 with conc. HCl after the addition of NaCl (30 g), and the mixture was extracted 4 times with water-saturated butanol. The butanol layers were mixed and washed once with 5% aq. NaCl. Water equal to 1/2 the butanol volume was introduced, and the resultant 2 phase system was concentrated to 200 ml by distillation. Sufficient 95% ethanol was subsequently added to make the final solution approx. 25% ethanol, and conc. HCl added until the pH was 4. The solution was then refluxed for 3-4 hrs, cooled and extracted several times with chloroform. The extracts were combined, washed with a sat. NaCl solution, and dried over anhyd. Na_2SO_4. The solvent was removed in vacuo, and the residue taken up in 100 ml. of benzene and counted.

Chromatographic Purification. The residue from 5 ml of the butanol fraction was chromatographed on Whatman No. 1 paper by the ascending method with the organic layer from a mixture of pet. ether (400 ml), ethanol (10 ml),

TABLE 1. Radioactive Counts of Crude Extracts*

	DPM/ml	Total DPM
Benzene solubles	11,900	2.77×10^6
Chloroform solubles	16,200	1.62×10^7

* The counts were obtained by dissolving a known amount of material in 15 ml of scintillation fluid (5 g of 2,5-diphenyloxazole and 300 mg of 1,4-bis-2-(5-phenyloxazolyl)-benzene per liter of toluene) and counting in a Nuclear Chicago Series 720 or Unilux II instrument. In general, the counts were taken over 10 min.

and water (90 ml). Prior to the chromatography the chamber had been lined with paper and allowed to equilibrate for 16 hr. with the organic layer at the bottom of the chamber and the aqueous layer contained in a beaker.

After 8 hr. the finished chromatogram was dried and a radioactive scan taken with a Vanguard Model 880 Autoscanner. The Rf value of the radioactive zone was the same as that of authentic non-radioactive smilagenin which was chromatographed at the same time on a separate part of the paper. Visualization of this latter material was accomplished by spraying with 25% trichloroacetic acid in chloroform and heating at 100° C for 10 min.

The radioactive material was recovered by extracting the indicated zone with chloroform and then was chromatographed on a 5 x 20 cm Silica Gel TLC plate with acetone: chloroform (3:1). Again, the Rf value of the radioactive zone detected with a glass plate attachment of Vanguard instrument was found to correspond to non-radioactive smilagenin chromatographed on the same plate and visualized with 50% H_2SO_4.

Purification of Smilagenin. The radioactive zone obtained above was recovered with chloroform and diluted with 500 mg of non-radioactive smilagenin. The material was recrystallized 4 times from acetone to yield 4 different sets of crystals. Each was then dried in vacuo for 24 hrs. and counted. The results are given in Table 2.

Each set of crystals was then acetylated by adding a minimum amount of pyridine-acetic anhydride and storing the solution overnight. The excess acetic anhydride was decomposed with ice, and the smilagenin acetate was recovered with ethyl acetate, washed with dil. HCl, water, and dil. $NaHCO_3$. Removal of the solvent gave material which was recrystallized from acetone, dried, and counted. Table 2 lists the results.

The smilagenin acetate was further transformed by first dissolving each of the 4 acetate fractions in a minimum amount of methanol, adding a few drops of 10% KOH, and refluxing for 2 hr. The sapogenin was taken up in ether and washed with water. Removal of the solvent gave smilagenin which was recrystallized from acetone.

The steroid was then dissolved in anhyd. pyridine and added to an equivalent amount of chromic acid-pyridine complex. The mixture was stirred overnight, then diluted with ethyl acetate. The precipitated solids were collected on Celite and washed with ethyl acetate, and the filtrate was washed with 10% HCl, water, and sat. $NaHCO_3$. After removal of the Na_2SO_4-dried solvent the resultant smilagenone was recrystallized from ethyl acetate, dried, and counted. The results are summarized in Table 2.

RESULTS AND DISCUSSION

Preliminary radioactive data obtained from the crude extracts (Table 1) appeared to indicate that the majority of the recovered radioactivity (83%) was associated with the sapogenins which were recovered with chloroform after hydrolysis of the butanol soluble material. The remainder of the radioactive material material was found in the lipid fraction (benzene solubles) as might be anticipated.

The chloroform soluble material was first subjected to paper chromatographic purification using a modified procedure of Heftmann and Hayden (1952). A radioactive scan of the developed chromatogram indicated a large zone with the same Rf value as that of an authentic sample of smilagenin chromatographed at the same time and a smaller radioactive zone at the origin line. To ensure purity the larger zone was recovered from the paper and rechromatographed on a silica gel thin layer plate using the procedure of Bennett and Heftmann (1962). We found the separation to be more complete and facile on dry plates rather than on water impregnated plates as reported. A scan of the plate indicated one main radioactive zone which had an Rf value corresponding to authentic smilagenin.

After extraction of the radioactive zone and isolation of the labelled smilagenin, it was diluted with pure non-radioactive smilagenin, and the combined material was then recrystallized 4 times from acetone. After each successive recrystallization, enough material was set aside for subsequent operations and derivatizations. As can be seen in Table 2, the radiochemical homogeneity of the smilagenin appeared to be good.

TABLE 2. ^{14}C Specific Activity in DPM/mole x 10^6 of Various Fractions and Derivatives.

Recrystallization Fraction	Smilagenin	Smilagenin Acetate	Smilagenone
1	453	306	363
2	475	341	301
3	482	353	375
4	463	355	381
Avg.	468	339	355

Each of the separate fractions obtained above was then acetylated, and each fraction of smilagenin acetate was purified by recrystallization to a constant specific activity. The specific activity for the various fractions, particularly 2, 3, and 4, deviated little from each other indicating good homogeneity among the individual fractions. A large difference occurs, however, if smilagenin acetate is compared with smilagenin. This discrepancy cannot be explained, but it seems to indicate a 25% impurity of a more radioactive material which has solubility characteristics similar to smilagenin. To verify the radiochemical purity of the material each individual fraction of smilagenin acetate was hydrolyzed with base to smilagenin which was then oxidized to smilagenone by chromic acid-pyridine. As shown in Table 2, the specific activity of the smilagenone fractions except for fraction 2 are in close agreement with one another. More important, though, is the good agreement between the specific activities of smilagenone and smilagenin acetate indicating that radiochemical purity was achieved.

These results confirm then the fact that smilagenin can be biosynthesized readily from mevalonic acid in Agave lechequilla. Also, it appears from the chromatographic data and the relatively small loss of radioactivity during derivatization that smilagenin is the main compound biosynthesized in this plant.

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OBSERVATIONS ON A LARGE LITTER OF THE SNAKE STORERIA DEKAYI

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Various authors have given the maximum number of young per brood for the brown snake, Storeria dekayi, as 24 Wright and Wright (1957), although Fitch (1970) records a brood of 27. On 31 July 1973 a large S. d. wrightorum (488 mm. total length, 390 mm. snout-vent length), collected 30 June 1973 about 3 mi. W Paxton, Ford County, Illinois, gave birth to 41 young. Notes on behavior, parturition, and brood variation of this litter were made. Since this information may be of interest to workers investigating the biology of the species, the detailed data are presented herein.

The specimen ate an earthworm on 13 July, which was the last time the snake accepted food until after parturition. On 28 July the snake was continuously probing about the cage. Any movement outside the enclosure caused the snake to coil and flatten its head and anterior body. The snake struck, with open mouth, at the observer on 30 July.

Several new-born snakes were observed in the cage at about 8:30 a.m. on 31 July. Parturition took place between 8:58 and 10:52 a.m. for the remaining snakes. Expulsion occurred in a few seconds to 1 minute. The female rested from 1 to 10 minutes between young. Frequently the snake would expel 2 or 3 young snakes with one contraction. These snakes were usually in separate membranes; at least one instance of twinning did occur however, the young snakes being born in 1 membrane and attached to the same yolk sack. This is apparently the first recorded instance of twinning in viviparous or ovoviviparous reptiles. One snake had already broken from the membrane before birth, and could be seen pushing against the inside of the mother's body wall.

As Smith (1961) did not comment on ontogenetic variation in brown snakes, it seems worthy to report that the juveniles under question have relatively longer tails than the adults (Smith, 1961: 240, Table 73). The ratios of tail length to total length ranged from .202 to .283. No effort was made to distinguish the sexes except in the case of the twins, which were both males; presumably the male snakes had the longest tails. The snakes measured 95 - 108 mm., mean 102.4 mm., total length, and 71 - 85 mm., mean 77.5 mm., s-v length. The twins mentioned above were 101 and 95 mm. total length, 75 and 70 mm. s-v length.

There was a 26.9 per cent mortality of the litter in the first 5 days; 12. 2 per cent died on 31 July. Only 1 snake was born dead.

The young appeared very emaciated; this may have been an important factor in the high mortality rate.

The baby snakes began feeding on small earthworms on 3 August. The mother of the brood began feeding again on 1 August. A partially digested snake was regurgitated by the adult; this instance of cannibalism was assumed to be accidental, since Storeria dekayi has not been known to prey upon other snakes.

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THREE NEGRO BUG STATE RECORDS FOR ILLINOIS (HEMIPTERA:CORIMELAENIDAE)

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ABSTRACT. -- The first records in Illinois of 3 negro bug species are presented.

The Family Corimelaenidae (negro bugs) is world-wide in distribution and contains several North American species. Although many of these species are common, very few have been studied in any detail. Thus, basic information (e.g., life cycle, geographical distribution) is either incomplete, inaccurate, or lacking for many of them.

The situation in Illinois reflects the general lack of knowledge of the family. An annotated list of the state's species was published over 50 years ago (Hart, 1919). McAtee and Malloch (1933) subsequently published a revision of the family which included additional information on Illinois species. Since that time, no new species have been added to the state list.

During the past 5 years, I have collected several hundred specimens of negro bugs in southern Illinois. These have been supplemented by a few specimens taken by other collectors. They have proven to represent several species, 3 of which are state records. This paper presents information on these records. The specimens are housed in the Entomology Collection of the Southern Illinois University Zoology Research Museum.

Genus Corimelaena White

Corimelaena (Corimelaena) agrella McAtee (in Hart, 1919). This species has been recorded from the District of Columbia, Maryland, Virginia, Texas (McAtee & Malloch, 1933) and Kentucky (Hart, 1919). Nothing is known about its life history.

During 1972-73 I found 30 adults in Jackson and Union Counties; the majority were collected in the La Rue-Pine Hills Ecological Area, Union County. They were taken between 20 April and 14 September, generally in low-lying shaded vegetation along roadsides. The only host plant recorded was Phlox pilosa L. from Pine Hills. Adults were noted feeding on the leaves 20 April, 1973.

Five additional adult specimens have been found by other collectors in Jackson and Williamson Counties 3 May-31 August, 1963-73.

Genus Galgupha Amyot & Serville

Galgupha (Galgupha) carinata McAtee & Malloch (1933). This species has been found in the following states: Maryland, Virginia, Georgia, Tennessee, Alabama, Mississippi, Louisiana, Oklahoma, Texas (McAtee & Malloch, 1933), Missouri (Froeschner, 1941), and Michigan (McPherson, 1970). The only information about its life history is a feeding record on Oxalis sp. in Virginia (Hoffman, 1971).

It was not surprising to find this species in southern Illinois since it had previously been collected in Missouri and Michigan. One adult ♀ was collected on 25 May 1973 and 1 adult ♂ on 27 July 1973. Both were collected sweeping exposed roadside vegetation in the La Rue-Pine Hills Ecological Area.

Galgupha (Galgupha) denudata Uhler (1863). This species has previously been found in the District of Columbia, Virginia, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana and Texas (McAtee & Malloch, 1933). Nothing is known about its life history.

During 1972-73, I found 11 adults in the La Rue-Pine Hills Ecological Area between 5 May and 29 September. They were collected sweeping a field in an early stage of secondary succession, and vegetation along roadsides. Both areas were partially shaded and at the base of the Pine Hills bluffs.

Three additional adult specimens have been found at Pine Hills by other collectors 7 May-17 September, 1966-71.

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FIRST RECORD OF THE NORTHERN STUDFISH, FUNDULUS CATENATUS (CYPRINODONTIDAE, PISCES), IN ILLINOIS

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The first record in Illinois of Fundulus catenatus (Storer) 1846, is reported.

The range of the northern studfish, F. catenatus (Storer) 1846, is the "upland tributaries of the Tennessee, Cumberland, and Green Rivers in Kentucky, Tennessee, Virginia, and Alabama; clear streams of the Ozark region in Kansas, Missouri, Oklahoma, and Arkansas; Red River tributaries in southwestern Arkansas; the Homochetto River in Mississippi; and the upper part of the east fork of White River, Indiana" (Moore, 1968). In Missouri it is one of the most common and widely distributed Ozark stream fishes (Pflieger, 1971). It occurs disjunctly in clear sand and gravel bottom streams ultimately tributary to the Mississippi River.

In July, 1973, a single female specimen (6.09 cm total length), was collected with an 8-meter minnow seine from the Cape Bend side channel of the Mississippi River (River Border Mile 48L, Alexander County, Illinois). Classical scale analysis indicates the specimen is of the 0 age group. Northern studfish were not found at the same site in 1972. The habitat at the collection site is atypical for the northern studfish, and it remains to be seen if populations will become established in Illinois streams.

Thomerson (1969) predicted that the Ozark population in Missouri would eventually cross the Mississippi River into Illinois. Smith (1965) included F. catenatus as a hypothetical addition to the fish fauna of Illinois, but he does not include it in his 1973 key (Smith, n.d.). In Smith's 1973 key, F. catenatus would key out in couplet 133 as F. diaphanus. However, F. diaphanus has approximately 20 vertical stripes, whereas F. catenatus has numerous parallel horizontal streaks.

ACKNOWLEDGMENT

The specimen was collected by Army Corps of Engineers personnel of the Waterways Experiment Station, Vicksburg, Mississippi. Dr. Jamie E. Thomerson, Faculty of Biological Science, Southern Illinois University, Edwardsville, Illinois, confirmed the identity of the specimen.

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STIPID GRASS "SEEDS" FROM THE OLIGOCENE AND MIOCENE DEPOSITS OF NORTHEASTERN COLORADO

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ABSTRACT.--Grass "seeds" from Middle Oligocene and Miocene deposits are reported.

The Tertiary flora of the High Plains of North America has been of interest to me because of the part it plays as a food source for the many small, herbivorous mammals found in the Oligocene and Miocene deposits in northeastern Colorado. Consequently, the two "seeds", that is to say caryopsis or grain with palea and lemma, reported here add to the fund of knowledge concerning this floral-faunal relationship.

Description of Specimens

One silicified "seed" (No. SIU PC664, Paleobotanical Collection, Botany Department, Southern Illinois University) was collected from a reddish sandstone channel deposit of Middle Oligocene age in the Cedar Creek member of the White River formation near the midpoint of the west border of sec. 2, T. 11 N., R. 59 W., Weld County, Colorado (14 miles east of Grover). This specimen (Fig. 1A-B) has the following dimensions (in mm): length of preserved part, 3.53; width at summit, 0.41; greatest diameter, 1.14; and diameter at broken base, 0.60. The summit shows no feature of descriptive value not seen in the figure. The lemma is smooth except for a longitudinal keel on the backside. The keel is strongest in the area of the summit and shoulder and terminates at the beginning of a cleft in the base of the lemma. The Palea exhibits a pebbly-like surface that is too weak to be described as tuberculate.

The second specimen (No. SIU PC665, Paleobotanical Collection, Botany Department, Southern Illinois University), also silicified, was collected from "Quarry A", a vertebrate fossil locality of earliest Middle Miocene age in the Pawnee Creek formation (Galbreath, 1953) in Martin Canyon, NE 1/4 sec. 27, T. 11 N., R. 53 W., Logan County, Colorado (nine miles west and five miles south of Peetz). This "seed" (Fig. 1C) has the following dimensions (in mm): length of preserved part, 3.39; width at summit, 0.40; greatest diameter, 0.86; and diameter of broken end of callus, 0.26. At the summit the diaphragm is well-preserved and shows the canal for the central nerve. The lemma is slightly

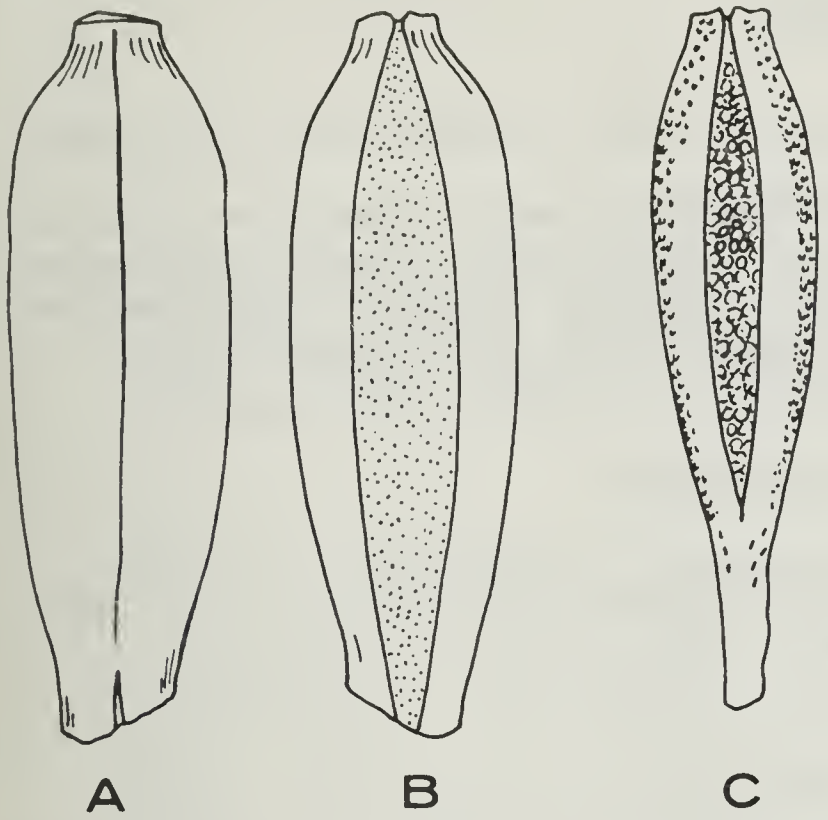

Figure 1.-- (A-B) stipid sp., No. SIU PC664, and (C) Stipideum nr schereri, No. SIU PC665, Paleobotanical Collection, Botany Department, Southern Illinois University.

weathered; tubercles certainly are more evident in some areas than in others but the distribution is irregular. I think the lemma must be described as tuberculate except for the narrow strip bordering each edge of the exposed palea. I presume that the non-tuberculated margins of the lemma correspond to the hyaline flaps noted by Elias (p. 42, 1942) on some fossil stipids and to be associated with two small lobes on the front of the summit. Elias (pl. 5, fig. 4, 1942) shows an excellent side-view of these lobes. The palea is tuberculate. Traces of stumps of hairs are visible on the upper part of the callus.

Discussion

It is deplorable to have but a single "seed" from each of the two levels despite continued searching since discovery of the specimens more than a decade ago. Consequently, the specimen from the Middle Oligocene deposit does little more than indicate the presence of a stipid-like plant with a hull essentially devoid of the ornamentation seen in geologically younger stipids.

The specimen from Quarry A appears to belong to the Parastipideum section of the genus Stipideum and possibly to Stipideum schereri Elias although the assignment is unsatisfactory with this sample of one.

Elias's work (1942) on the Miocene-Pliocene grasses of the High Plains include remarks about stipids found in the Late Tertiary deposits in northeastern Colorado. In Logan County specimens are found, together with Celtis willistoni (Cockerell) Berry, in deposits of the Pawnee Creek formation containing the Kennesaw and Vim-Peetz local faunas of Late Miocene age. While specimens of Stipideum are numerous, most are damaged. None-the-less, the combination of features gleaned from examining collections show

Stipideum coloradense Elias to be the most common kind present.

It is not unusual to find closely packed concentrations of Stipideum or Celtis, or both, that suggest that these specimens had been gathered and stored -- possibly in burrows. On two occasions such concentrations were associated with skeletons of geomyoid rodents.

Acknowledgements

The Zoology and Botany Departments at Southern Illinois University provided aid and facilities for this study. In particular, I want to thank Professor John Voigt for helpful consultations.

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CORRESPONDENCE

Letters to the Editor are welcomed and will be published, if found suitable, as space permits. They must be typewritten single spaced (including references), must not exceed 2 pages in length and will be subject to editing and possible abridgment.

USE AND ABUSE OF PUBLIC AREAS

To The Editor - The purpose of this letter is to comment upon W. D. Klimstra's paper PUBLIC AREAS: MULTIPLE USE OR MULTIPLE ABUSE? (Trans. Ill. Acad. Sci. 62-2:218-220, 1969). In some cases I am disagreeing with Klimstra's views and in others I am agreeing. I also wish to add a few of my own philosophies on the use of public lands for recreation. I am speaking from the outdoor recreation manager as well as from the resource manager viewpoint, as I am involved with both fields.

To start off, I must comment that I agree with Klimstra's feeling that there are many areas which are far too valuable ecologically to be used as recreation areas. Allerton Park in Piatt Co., Ill. is an example. One portion of the park has been disturbed by man for many years and has remained the center of most of the recreational activities of the park. This area contains formal gardens, statuary and trails in the riverbottom woodlands which have been used and continue to be used for recreation. On the opposite side of the park is a nearly undisturbed area which traditionally has been used only for ecological studies of the flora and fauna of the area. Since the "Save Allerton Park" movement some years ago (in efforts to stop a reservoir project) the recreational use of this portion of the park has greatly increased. The price of the publicity brought about to preserve the park from destruction have caused irrepairable damage to this fine outdoor laboratory. Such could become the case if areas such as the Pine Hills and Jackson Hollow in the Shawnee National Forest see increases in use.

There are strong differences in outdoor recreationists just as there are strong differences in hunters. True campers and other responsible outdoor recreationists received the blame for damage to natural areas just as unjustly as do hunters for the acts of poachers. Those who would run a trail bike through Jackson Hollow (as I have observed many times) are no more the average outdoor recreationist than the one who would shoot a bald eagle or jacklight a deer is a true hunter.

Part of the misconception involved here is in the definition of multiple-use. The policy of multiple-use not only includes actual uses such as logging, mining, grazing, etc., but also in appropriate situations preservation. Preservation is also a type of use where the land is not altered in any fashion.

My last comment is that recreation administrators and resource managers must join forces. Resource manager must conduct research on recreation impact on natural areas and provide findings on which the recreational resource manager can base his management decisions. This will also require a new breed of recreation administrator, one that is trained just as thoroughly as an ecologist as he is trained in recreation, forestry, etc. This might be brought about by transferring recreation departments in our universities from the traditional P.E. Departments to the life science, biology, wildlife, forestry or other similar resource oriented department. I think it is time that all of us, recreation specialists, ecologists,foresters, and other resource managers, get up and start working together. We all have an obligation to the natural and human resources of this country and let's start living up to that obligation instead of sitting around fighting each other.

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"NEW LOOK"

To The Editor - The first issue (67 #1) of the "new look" in the Academy TRANSACTIONS has been received. In your editorial (p. 145) of the issue, you provided for the option of comments on the photographic reproduction process for the TRANSACTIONS. To be candid, I was most disappointed to see the shift from a top-quality printed product to a second-rate duplication process. In my opinion, the TRANSACTIONS stands not only as the present organ of scholoarly scientific works, but also as the progenitor of works yet to come. If an article is deserving of publication, it also deserves the dignity of top-quality editorial treatment--from commas to the printed word. I realize fully the financial problems involved in maintaining the "old look" in the TRANSACTIONS. But by whatever means--page costs, reduced acceptance rate, etc.--let's keep the TRANSACTIONS as a quality product. After all, it is the major tongue of the Academy--and, hence, of our state's scientific community.

RONALD F. LABISKY
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CORRESPONDENCE

To The Editor-, I for one would like to object to the present format of the TRANSACTIONS of the Illinois State Academy of Science. I am aware of the fact that there has been a curtailment of funds available for publishing the TRANSACTIONS but I am not sure that the curtailment of funds should have resulted in such a product. Let me go on to explain.

The two most important things that the Academy does is publish the TRANSACTIONS and hold an annual meeting. All of our other activities are "nice", but are not necessary or essential. Since the annual meeting should pay for itself, then all the dues from the members should go for publishing the TRANSACTIONS. However, in the past when we did not have to spend all of our dues for the TRANSACTIONS, the Academy became involved in doing other things which cost money. At the present time I feel that nearly 100 per cent of the dues should go for publishing the Transactions, and nothing else.

Other state academies are able to put out a printed transaction with the dues that they receive from their members. A good example of this is the Kansas Academy of Science. If they can, why can't we?

I think a good number of members of the Illinois State Academy of Science retain their membership since this is a potential place to publish articles as well as a valuable journal to have. I think that these two reasons will disappear under the new format of the TRANSACTIONS and the Academy will lose many members. I have heard many scientists say that they would not consider publishing articles in the Transactions as it appears now.

As a long-time member of the Academy, I offer these suggestions with the hope that some means can be found for keeping the quality of the TRANSACTIONS high and the Academy viable.

DONALD F. HOFFMEISTER
University of Illinois
Urbana-Champaign

CORRESPONDENCE

To The Editor - As a past member of the TRANSACTIONS' editorial board, as well as a contributor to the TRANSACTIONS, it was with real pleasure that I studied vol.67#1 observing the quality of the offset-lithoprinting directly from typewritten manuscripts.

In 1968, I published a physics paper in the TRANSACTIONS. At that time, I looked forward to sending along some other things, as well as also encouraging some of my colleagues to do so. You can imagine my chagrin when my paper was duly accepted and I then received galley proof! The mathematical typesetting work was of quite abominable quality (however much we might commend the ingenuity on the typesetter in hitting upon the idea of using toppled over M's in place of Σ's for summation signs). Well, this experience finished me with the TRANSACTIONS. However, with the aid of IMB "Selectric" symbol elements, plus dry-transfer letters, it is possible to put up a mathematical-physical manuscript in typewritten form which looks quite good. I therefore look forward to sending you a paper before the end of the Fall '74 semester.

HERBERT H. SNYDER
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GROUND-WATER LEVEL IN THE FLOOD PLAIN AND ADJACENT UPLANDS OF THE SANGAMON RIVER

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ABSTRACT

The influence of river level, precipitation, and evapo-transpiration on the water table fluctuations of the streamside forest ecosystem was determined from observation well data at four locations in the upper Sangamon River bottoms and adjacent uplands. Water levels in the soil profile of the flood-plain areas of the streamside forest were strongly controlled by the level of the water in the stream channel. Changes in the upland water table, however, were not closely correlated to river level changes. Precipitation was the environmental variable most strongly influencing changes in the upland ground-water system. Evapo-transpiration losses in mid-transect areas may exceed infiltration of ground water from the river and drainage from higher levels during certain summer periods. An hypothesis concerning the possible changes which may occur upon construction of the William L. Springer Project is discussed. The study is a contribution of the Springer-Sangamon Environmental Research Program.

INTRODUCTION

Flooding in the streamside forests and man-affected adjacent areas of the Sangamon River valley is a natural, although often dramatic event. While much is known about fluctuations in the Sangamon and other Midwestern rivers, little is known of the dynamics of the groundwater table in the areas adjacent to the stream channel. Flood control dams and levees have been a common attempt to mitigate the dramatic flooding events. The effect of impounding a river in raising the surface water elevation is a simple prediction to make. The prediction of the effect of impounding a flowing stream on the ground-water levels in adjacent lands is much more difficult. The current study was initiated to determine the influence of river stage on the level of ground water in the streamside forest and adjacent upland forests in the Sangamon River valley of east-central Illinois. The study is a contribution to the Springer-Sangamon Environmental Research Program, a multi-disciplinary research program designed to study the dynamics of aquatic and streamside forest ecosystems and to monitor ecological changes in the Sangamon River valley before, during, and after construction of the William L. Springer Lake Project (Bell, 1972). Knowledge gained in this area would not only be of importance in the streamside forest ecosystem, but would help predict effects of river impoundment on the water table of adjacent agricultural and urban lands as well.

METHODS

Ground-water observation well transects were established in the upper Sangamon River basin at four study areas. The Allerton Park Bridge transect (Sec. 21, T18N, R5E, 3rd P.M.; 40°00'N, 88°38'W) traverses a very broad natural flood plain with little topographic change and provides an excellent location to observe the influence of river stage and distance from the river bank on the ground-water table dynamics. The transect consists of 14 wells, spaced at 25 m intervals in a line perpendicular to the river channel.

A gradient of elevations running from the streamedge up into upland, unflooded areas is traversed in the Upper Allerton Park, Hart Woods, and Oldweiler Woods sites. The Upper Allerton Park series (Sec. 21, T18N, R5E, 3rd P.M.; 40°00'N, 88°38'W) contains six observation wells covering the elevational gradient from the stream bank at 628 ft. to an upland elevation of 642 ft. and is located approximately 400 m upstream from the Allerton Park Bridge site. Allerton Park is located approximately 4 miles southwest of Monticello, Illinois. The observation-well transect in the Nettie Hart Memorial Woods, a University owned natural area north of Mahomet, Illinois, (Sec. 26, T21N, R7E, 3rd P.M.; 40°13'N, 88°21'W) consists of three flood-plain wells and two upland wells spaced at 20 m intervals. The transect of wells in Oldweiler Woods (Sec. 24, T17N, R3E, 3rd P.M.; 39°55'N, 88°49'W) contains eight wells, spaced at 25 m intervals, and covers approximately 100 m of flood plain and 75 m of uplands. The Oldweiler Woods is a privately owned woodland on the Sangamon River south of Argenta, Illinois.

The study areas were chosen not only to provide a diversity of sites for the study of the effects of environmental variables and river level on the ground-water table, but to provide pre-impoundment data for areas of the Sangamon River upstream from the construction site of the Springer Dam. The Oldweiler Woods flood plain will be in the zone of the river to be completely inundated. The upland wells at Oldweiler Woods will, however, provide excellent continuing data on the influence of the Springer Lake on the water table of the upland forests adjacent to the impoundment. The two sites in the Robert Allerton Park lie in the portion of the river scheduled to experience a change in the natural flooding pattern and will be important sites to document alterations from the pre-impoundment condition. The Hart Woods series provides ground-water data in the control areas of the river basin; those areas unaffected by the Springer Lake Project.

An observation well consists of a 10-foot length of 3/4" P.V.C. pipe drilled with drain holes and enmeshed in plastic screening. The pipe is placed in a 2" auger hole and encased in pea gravel. Ground water flows into the well through the small holes until equilibrium with the water table is reached. The elevation of the water table is determined by blowing into a calibrated length of copper tubing lowered into the well and noting the depth at which bubbling is heard. Elevation of each observation well head was determined with a surveying level from established bench marks. The water table elevation at each well was determined at weekly intervals.

River stages for the Allerton Park sites were recorded at the Allerton Park Bridge by a continuous recording stream edge. River levels for the

Oldweiler Woods and Hart Woods sites were determined as the level of the ground water in the well closest to the stream edge. Precipitation was measured by tipping bucket rain gages in weather stations located in the Upper Allerton site, the Hart Woods site, and the Oldweiler Woods site.

RESULTS

The results of the analysis of the relationship between river stage and the level of the water table for the Allerton Park Bridge site are summarized in Table 1. For all river stages the level of the ground-water table is strongly correlated to the water level in the river channel. When all samples are considered, river level accounts for 96% of the variance in the water table at a distance of 25 m from the river and still accounts for 90% of the variance in well 13 at a distance of 300 m from the river. When river stage is separated into flood, high flow within or near bank level, and low flow, additional information appears. Under low flow conditions of less than 300 ft^3sec^{-1} (627 ft), a very slight increase in ground-water level occurs with increasing distance from the river. Under conditions of more rapid streamflow, the ground-water table in the land near the stream is depressed as the flow rate downstream creates a pressure deficit in the flood-plain ground water system and water is being pulled into the stream flow faster than it is replaced from adjacent upland areas. Under conditions of river levels in excess of 630 ft, ponding of the water in the areas of the observation wells results in a similar condition to the low flowages where increasing distance from the water's edge results in slight increases in the elevation of the water table. Under most conditions, the water table in the flood plain can be determined fairly closely from the level of the water in the stream channel. As river discharges increase, ground-water levels near the river edge may actually be slightly below the river stage.

Table 1. Ground-water observation well data for flood plain near the Allerton Park Bridge. Elevation of well in feet above M.S.L. Distance from river in meters. Data for ground water level listed as average difference and standard deviation (in feet) from river level for flood, high flow, and low flow river stages.

Well No.	Dist. from river(m)	Elev.(ft)	Difference from river level		
			Flood stage 630 ft	High flow 627-630 ft	Low flow 627 ft
1	0	628.45	--	-0.09±0.30	0.02±0.02
2	25	629.74	--	-0.09±0.14	0.19±0.04
3	50	629.66	--	-0.10±0.14	0.31±0.04
4	75	629.86	--	-0.12±0.13	0.30±0.04
5	100	629.30	--	-0.03±0.13	0.39±0.05
6	125	629.45	--	0.08±0.15	0.50±0.04
7	150	630.54	0.03±0.02	0.19±0.12	0.62±0.05
8	175	631.60	0.09±0.14	0.54±0.20	1.10±0.04
9	200	631.69	0.22±0.17	1.01±0.17	1.47±0.05
10	225	631.75	0.01±0.15	0.77±0.24	1.25±0.06
11	250	632.11	0.13±0.21	1.19±0.21	1.69±0.05
12	275	632.45	1.15±0.09	1.72±0.24	2.19±0.22
13	300	631.78	0.36±0.13	1.18±0.20	1.62±0.07
14	325	632.20	0.50±0.14	1.18±0.20	1.70±0.05

Flood-plain water tables in the three elevational gradient sites were also strongly influenced by the level of the water within the river channel. Figure 1 presents the relationship between elevation of the river and elevation of the flood-plain water table at a distance of 50 m from the streambank at the Upper Allerton, Hart Woods, and Oldweiler Woods study sites. River level accounted for 84% of the variance in the ground-water table when the three sample areas were analyzed together.

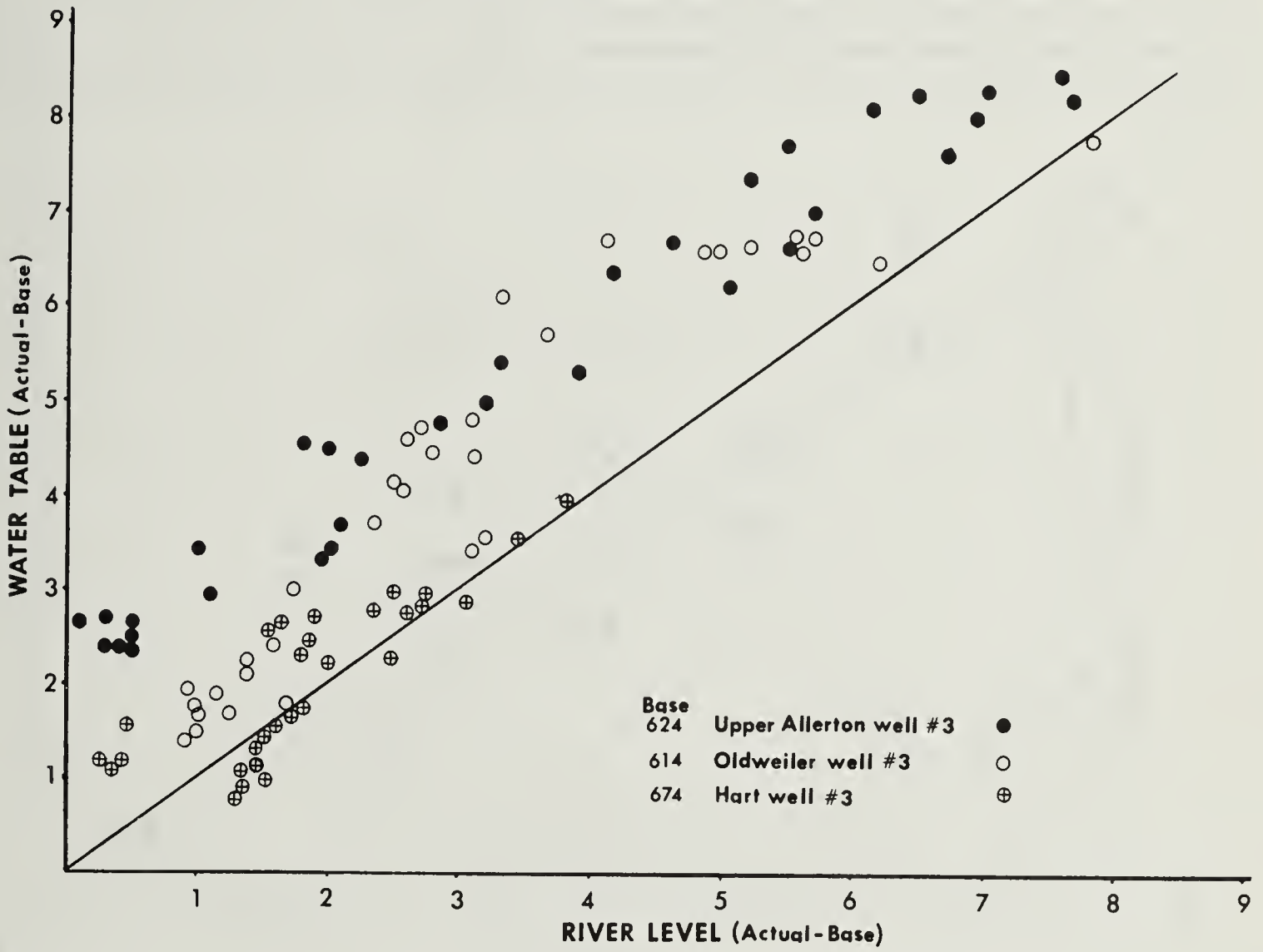

Fig. 1. Relationship of river stage to ground-water table at approximately 50 m from the river at the Upper Allerton, Oldweiler Woods, and Hart Woods sites. Data are graphed as the actual elevation (ft) above a base elevation for each site. Diagonal line represents equal river and water-table levels.

The influence of river level on ground water over the entire elevational gradient can be determined by calculating the fraction of variance in ground-water levels accounted for by variance in river level, for each well in the transect. The percent of the variance (coefficient of determination) accounted for in the water table by river level along the elevational gradients at the Upper Allerton and Oldweiler Woods sites is shown in Figure 2. River level accounts for more than 80% of the variance in the ground-water table near the river's edge. However, with increasing distance, the coefficients of determination drop to the 40-60 range at distances of 50-75 m from the river and remain fairly constant to the edge of the upland at about 125 m from the river and about 2 m (vertical distance) above the bank elevation. In the upland zone, the coefficient of determination drops to 22 at 150 m from the river (5.3 m vertical distance above the bank) and 7 at 175 m (9.2 m vertical). Weekly total rainfall, measured at the weather station in the Oldweiler uplands accounts for approximately 70% of the variance in weekly measurements of the water table at the observation wells located 5.3 and 9.2 m above the river bank. Weekly rainfall accounted for only approximately 15% of the variance in the flood-plain water table. While river level appears to be the strong determinant of ground-water levels in the flood-plain, rainfall is the environmental variable most strongly controlling upland ground-water levels.

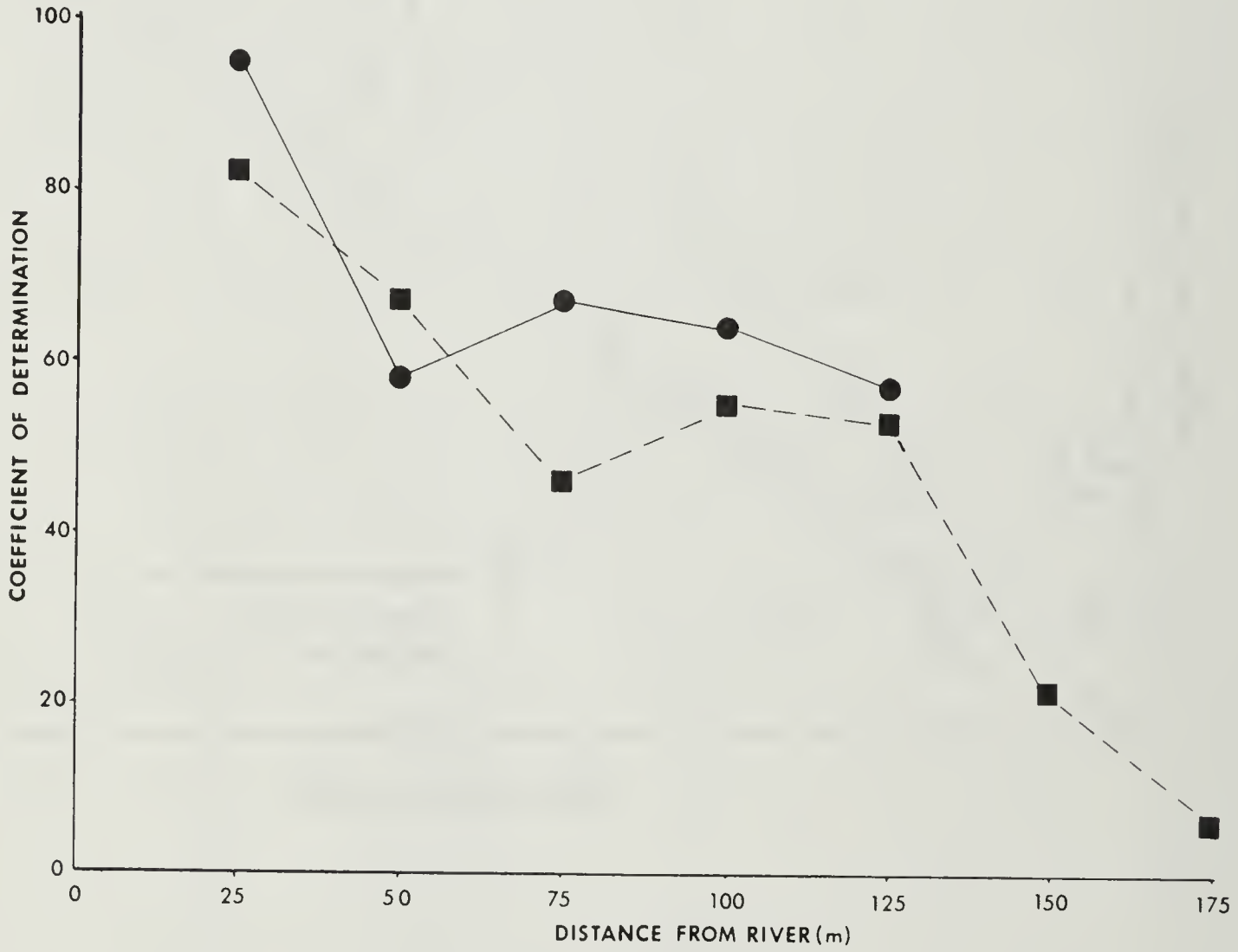

Fig. 2. Coefficient of determination between river level and water table vs. distance from river bank at Oldweiler Woods (dashed line) and Upper Allerton (solid line).

During the growing season evapo-transpiration losses from the vegetation can markedly affect the ground water levels in mid-gradient areas during periods of low river flow and low precipitation. The scatter diagram for the relationship between river level and ground-water level at Oldweiler Woods well #5 (100 m from the river bank) shows a remarkable number of readings below the river level (Fig. 3). Most of these values occurred in the period of low river flows and low precipitation during August and September. Evapo-transpiration of moisture from the streamside forest trees appears to be occurring more rapidly than the influx of ground water from the upland sources by precipitation and run-off or from infiltration of water from the river.

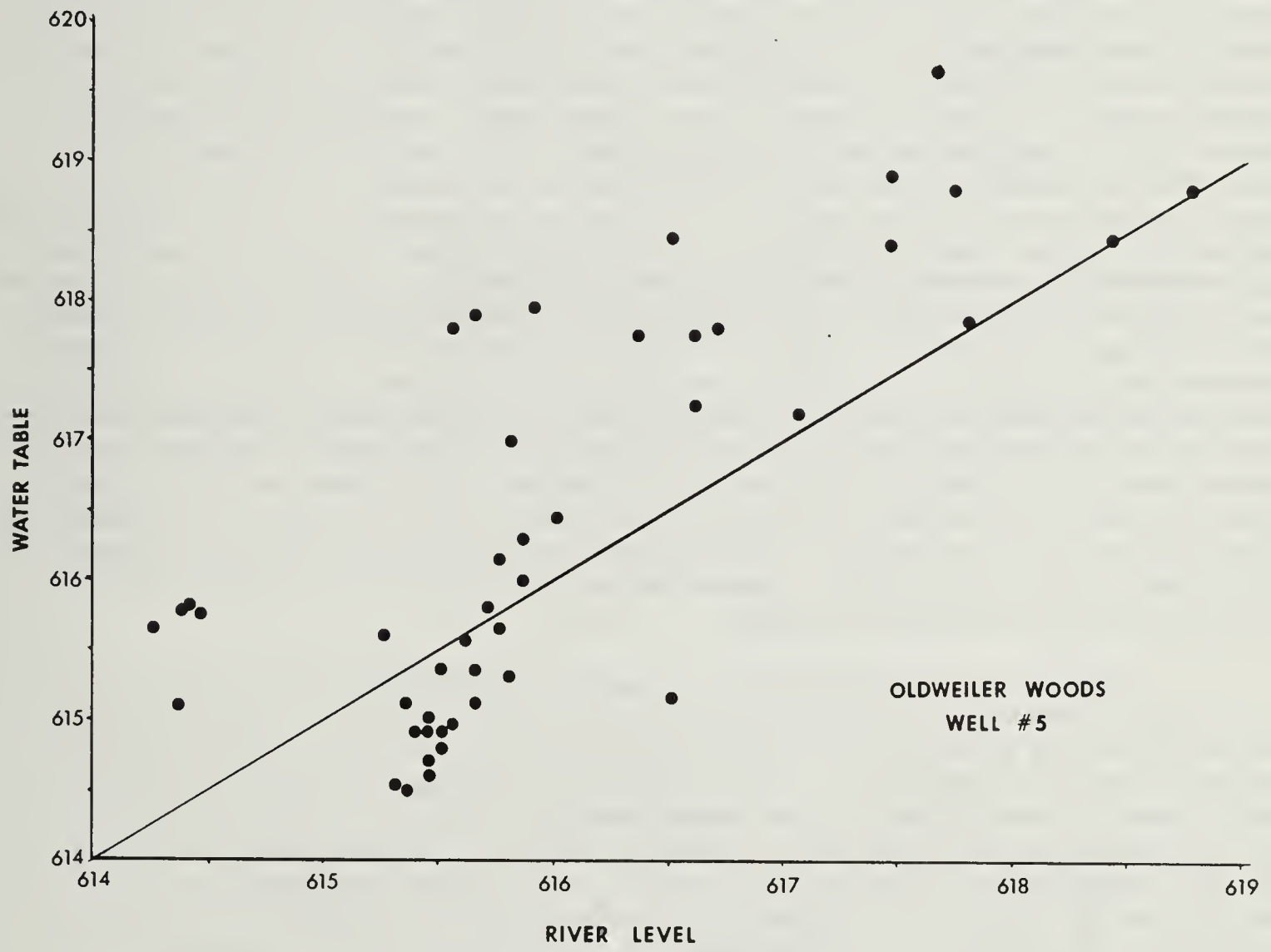

Fig. 3. Relationship of river stage vs. ground-water level at Oldweiler Woods well #5, 100 m from the river bank. Diagonal line represents equal river stage and water-table level.

DISCUSSION

The streamside ecosystem is under the strong control of the hydrologic fluctuations of the river. Much of the controlling influence in the vegetation is generated by magnitude, frequency, and duration of flooding periods (Bell 1974a, 1974b). The naturally occurring plants and animals have developed under the influence of the flooding regime and are tolerant of the flooding conditions. Cultivated crops planted into the flood susceptible areas, however, are severely affected by the anaerobic conditions of flooding and soil saturation (Bergman, 1959; Conway, 1940; and Kramer and Jackson, 1954). Clearing forested areas and tile-draining former prairie regions has apparently had little effect on the flooding regime of the Sangamon River (Kendeigh, 1973). It follows from the strong correlation of the river level to ground-water level that the fluctuation in the level of the water table in the flood-plain areas of the Sangamon River is much the same today as they were in primitive times.

Impounding the Sangamon River by the Springer Dam, however, will vastly alter the hydrologic events of the stream. From information derived from the present study and the predicted hydraulic changes to occur in stream levels upon construction of Springer Lake, it is possible to formulate an hypothesis concerning the changes which may occur in the water table of adjacent areas. It seems probable that ground-water levels in flood-plain areas will be maintained at or slightly above the level of the normal-use pool during periods of normal stream flow. Water table levels in the adjacent areas greater than about 10 feet above the normal pool will be controlled by factors other than lake level. In the zone of the river above permanent impoundment but within the influence of flood control, ground-water levels will be affected in relation to the alteration in stream dynamics. In the case of the Springer Lake Project, areas of the Upper Sangamon River basin between elevations 623 and 641.7 ft occur within the flood control pool. Areas of upland not previously affected by floodwaters will now experience anaerobic conditions in the soil profile during periods of high water. Ground water in areas above the flood-control pool will continue to respond to precipitation, evaporation, and drainage as prior to the flood control project. Drainage in these areas could be impeded if drain tile outlets lie at elevations below the flood control elevation. Impounded waters could prevent normal flow of tiles during flood-control periods.

Effects on the biological organisms inhabiting the Sangamon River valley will undoubtedly be determined by the ability of the living organisms to tolerate the altered conditions imposed by construction of the William L. Springer Dam and Reservoir. A thorough understanding of existing physical environmental conditions in the streamside ecosystem is essential to the understanding of the streamside forest ecosystem. Knowledge of the dynamics of the ground-water table in this habitat is of major importance in the establishment of this understanding. More complete information on species tolerances is required for assessment of the effects of the changing soil saturation conditions on the streamside forest ecosystem.

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TERRACES, MEANDER LOOPS, AND ARCHAEOLOGY IN THE AMERICAN BOTTOMS, ILLINOIS

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ABSTRACT--Utilizing association of dated archaeological artifacts and sites, plus the principles of superimposition, a dated chronology has been established for the first terrace, the floodplain surface, and 24 extinct river channel segments in the American Bottoms portion of the central Mississippi River valley. These data suggest that the last deposition on the first terrace (Festus) occurred after 10,000 radiocarbon years ago but prior to 9000 B.P., that the surface of the present floodplain was formed after 5000 B.P. but some years prior to 2800 B.P., and that some of the river channel remnants (meander loops) ceased to exist as viable portions of the river well prior to 2800 B.P.

In situations where chronologies of geological events have been established, archaeologists have often utilized these chronologies to establish sequences of cultural events, primarily by the association of cultural artifacts or sites with particular geological features. Although less frequently used, the opposite edge of the sword is equally sharp; when the cultural chronology is well established, geological features can be dated by their association with diagnostic cultural remains. This paper is an attempt to determine, by association of archaeological remains, the age of formation of the surface of the floodplain, the first terrace above the floodplain, and a number of extinct river channel remnants (meander loops) within the American Bottoms.

LOCATION AND DESCRIPTION

The American Bottoms is a wide expanse of valley floor along the Mississippi River in Illinois, roughly opposite St. Louis, Missouri, and opposite and mostly downstream from the mouth of the Missouri River. Summarizing from previous descriptions of the physical characteristics of this area (Fenneman 1911; Branom 1941; Bergstrom and Walker 1956), the greatest width east-west is approximately eleven miles and occurs just north of the Madison-St. Clair county line. The valley narrows abruptly on the north near

Alton, Illinois, and on the south near Dupo, Illinois, a distance of approximately 25 miles.

The bulk of this bottomland area is floodplain; i.e., it was, prior to modern leveeing projects, subject to overflow from the Mississippi River, and it varies from ca. 415 feet above mean sea level at the northern end of the Bottoms to ca. 405 feet above sea level at the southern end. Most of this floodplain area is scarred by a number of extinct river channels which exhibit various degrees of filling. Prior to modern drainage, approximately one-sixth of the total area of the American Bottoms consisted of lakes and swamps of a permanent enough nature to be worthless as agricultural land (Branom 1941: 91), and all of these lakes and swamps apparently laid within the channel remnants.

At the northern end of the Bottoms, a sandy terrace of Pleistocene age rises ca. 30 feet above the floodplain (ca. 445 feet above sea level). This feature, which is informally referred to as the "Wood River Terrace" by Bergstrom and Walker (1956: 30-31) and most archaeologists working in the area (e.g., Munson 1971), has been formally designated as a portion of the Festus Terrace of the central Mississippi River valley by Robertson (1938), and the Festus Terrace correlates exactly with the terrace system in the vicinity of the mouth of the Illinois Valley which Rubey (1952) refers to as the Deer Plain Terrace.

METHODS OF DATING

Archaeological sites must post-date the formation of the surface upon which they rest. Therefore, a terrace or the surface of a floodplain will be older than the oldest archaeological assemblage found upon it. A corollary assumption is that if a human population exists in a general area, any new surface will be "colonized," at least to some extent, soon after it becomes available for habitation. A potential source of confusion which exists here, however, is that individual artifacts might be fabricated and lost or discarded at an earlier date and then transported by the same agency (in this case water action) which was responsible for the formation of the terrace or floodplain. However, such specimens would be expected to show evidence of "rolling" and since none of the artifacts dealt with in this study show such evidence this possibility can be ignored.

The sequence of formation of meander loops, from a straight segment of river, to a wide and expanding loop, to cut-off and creation of an "oxbow" lake, is well understood (Leopold and Langbein 1966; Lathrap 1968: Fig. 2). Given this sequence, the position of dated archaeological sites in relationship to oxbow lakes can be used to establish the dates before which the meander loops were cut off (i.e. ceased to function as viable portions of the river). If an archaeological site is found immediately adjacent the inside (convex) bank of a meander segment, it is certain that the site was established after, or at most only a few years prior to, the date when this segment was cut off; if the site had

been established prior to the migration of the meander, it would have been destroyed; if it had been established after the meander had passed, but well prior to the cut-off, the bank would have migrated away from the site. Sites found on the surface immediately adjacent the outside (concave) edge of a meander segment also must have been established after or only a few years prior to the date of cut-off; sites established along the concave bank of a viable meander would have soon been eroded away, or, in a situation where a meander migrated up to a site which pre-dated it and then stopped, the site would be buried beneath the alluvium of the natural levee.

THE ARCHAEOLOGICAL CHRONOLOGY

The sequence of prehistoric cultural periods or phases in the Midwestern United States has been well-established by stratigraphic excavations and by several hundred radiocarbon age determinations. These periods and their age-ranges as extrapolated from radiocarbon determinations are, from latest to earliest, as follows:

Period	Age B.P.
Late Mississippian	400- 700
Early Mississippian	700- 1000
Final Late Woodland	900- 1100
Initial Late Woodland	1100- 1600
Middle Woodland	1600- 2200
Early Woodland	2200- 2800
Late Archaic	2800- 5000
Middle Archaic	5000- 8000
Early Archaic	8000-10,000
Clovis	10,000-12,000

Sites, or at least unrolled artifacts, of all these periods except Clovis have been discovered at various locations within the American Bottoms during archaeological surveys by myself (Munson 1971), by Harn (1971), and by others as recorded in the files of the Illinois Archaeological Survey.

AGE OF THE FESTUS TERRACE

On geological grounds, there has been some confusion as to the exact temporal position of the Festus Terrace. Robertson (1938: 236), who originally defined it, simply referred to it as a Wisconsinan feature. Subsequently Rubey (1952: 96), who refers to the feature as the Deer Plain Terrace, argued for a post-Kankakee Torrent alignment (i.e., post-ca. 14,000-15,000 B.P.). More recently Leighton (1957: 1037) argued that this terrace could be traced to the Bigstone Moraine in Minnesota, which he interpreted as a Valderan feature. Wright (1957: 1038), however, correlated the Bigstone Moraine with the Mankato Advance, and it is apparently on this basis that Willman and Frye (1970: 116) assign the terrace to a late Woodfordian, pre-Two Creeks position (i.e., pre-ca. 12,500 B.P.).

Whatever the temporal placement of the Bigstone Moraine and its relationship to the lowest terrace of the Mississippi Valley, the archaeological evidence strongly suggests an early Valderan, rather than a late Woodfordian, alignment for at least the final deposition upon the Festus Terrace. Although Clovis points are fairly commonly recovered from elevations higher than the surface of this terrace in the vicinity of the American Bottoms and the mouth of the Illinois Valley, none are known to have come from its surface or lower elevations, thus suggesting that the surface was not present (or at least was not inhabitable by man) until after 10,000 years ago. Projectile points diagnostic of the Early Archaic Period, specifically the types Dalton-Meserve and St. Charles, do however occur in some quantity upon the surface of this terrace both within the American Bottoms and in the lower Illinois Valley. St. Charles points are at best only loosely dated within the ca. 8000-10,000 B.P. time-range (or perhaps slightly later), but it seems definite that Dalton-Meserve points were not used after about 8500 years ago and it is likely that their use does not post-date ca. 9000 B.P. The archaeological data thus suggest that the terrace was still being formed at 10,000 B.P., but that formation had ceased by 9000 B.P., a date approximately mid-way in the assigned time-range for the Valderan Substage.

AGE OF THE FLOODPLAIN

The present floodplain is the surface of the recently classified Cahokia Alluvium Formation (Willman and Frye 1970: 75). Neither Clovis nor Early Archaic materials have been recovered from this surface and only one site of the Middle Archaic Period (South Roxana, Ms-66) has been discovered at a floodplain elevation. Significantly, however, this site is located upon the flank of the Festus Terrace rather than upon the floodplain proper, and consequently is perhaps not relevant to the dating of the present floodplain. It is only during the Late Archaic Period that sites become general upon the floodplain surface.

Additional archaeological support for a post-Middle Archaic age for this surface comes from recent dredging activity in the west-central portion of the Bottoms in which unrolled artifacts assignable to the Late Archaic Period (and presumably dating to the early portion of this period) were recovered at a depth in excess of 25 feet below the present floodplain. Furthermore, Willman and Frye (1970: 37) report that in this general vicinity an upright tree trunk was discovered at a depth of 50 feet below the present floodplain surface which yielded a radiocarbon age of 6600 B.P.

Available data therefore suggest that at 6600 B.P. at least portions of the floodplain surface were some 50 feet lower than modern levels, and that by some time after the beginning of the Late Archaic Period (ca. 5000 B.P.) some portions were still in excess of 25 feet lower than present, but that floodplain formation, with the exception of natural levees and point bars associated

with river channels, had ceased some time prior to 2800 B.P. This in turn suggests that floodplain formation in this portion of the Mississippi Valley is comparable in age to formation in the lower Mississippi Valley (from Cairo, Illinois to the mouth) where geological evidence suggests a final "wave of alluviation by braided streams . . . 4,000-5,000 years ago (Saucier 1968: 74-75).

AGES OF THE VARIOUS MEANDER LOOPS

Segments of 24 extinct meanders are apparent within the floodplain of the American Bottoms (Fig. 1). In several instances it can be demonstrated that two or more of these meanders were parts of a single extinct channel; examples are the Spring Lake and Jones Park meanders, the Choutou Slough-Gabaret Slough-Horseshoe Lake channel, and at a later period the Choutou Slough-Gabaret Slough-Dead Creek channel. It might be possible to correlate other segements, but such correlations are much less convincing. Consequently, except for the above mentioned channel reconstructions, consideration will be given only to single meander loop segments.

Although archaeological sites have not been discovered in association with every one of these channel segments, there are, nevertheless, numerous sites in key positions, and these, combined with the relative chronologies derived from superimpositions of various channel segments, allow one to reconstruct a fairly tight chronology of channel changes.

The last channel change to have occurred in the American Bottoms, as determined by the superimposition of channel segments, was the cut-off of Cahokia Slough by the modern channel of the Mississippi. Historical data can be brought to bear here since the French mission at the village of Cahokia was established in 1699 (Fortier 1908) and this village lies immediately adjacent the outside margin of Cahokia Slough, which was described as an "arm" of the river (rather than the channel) in 1699. Cahokia Slough is superimposed upon the older Choutou Slough-Gabaret Slough-Dead Creek channel, which in turn is superimposed upon the Horseshoe Lake meander. The methodology employed here has already been applied to the Horseshoe Lake meander by Bareis (1964: 89), who argued that lateral movement of this feature had ceased prior to the end-date of the Final Late Woodland and Early Mississippian periods (ca. 900-1000 B.P.). This was determined on the basis of the positions of the Powell mound group and village site (Ms-2-2) and the Mollenbrocks mound and village (Ms-37), which lie immediately adjacent the outside margin of this meander.

The Edelhardt Lake meander, which pre-dates the Horseshoe Lake meander, must have a cut-off date prior to 2200 B.P. since the Early Woodland Miller Lake site (Ms-34) is located on a point bar remnant adjacent the inside margin. Cut-off of the McDonough Lake meander, which is superimposed upon by the Edelhardt Lake meander, pre-dates 2800 B.P. on the basis of the position of the Late Archaic McDonough Lake site (Ms-46) adjacent its outside margin. The Spring Lake-Jones Park channel segment is also

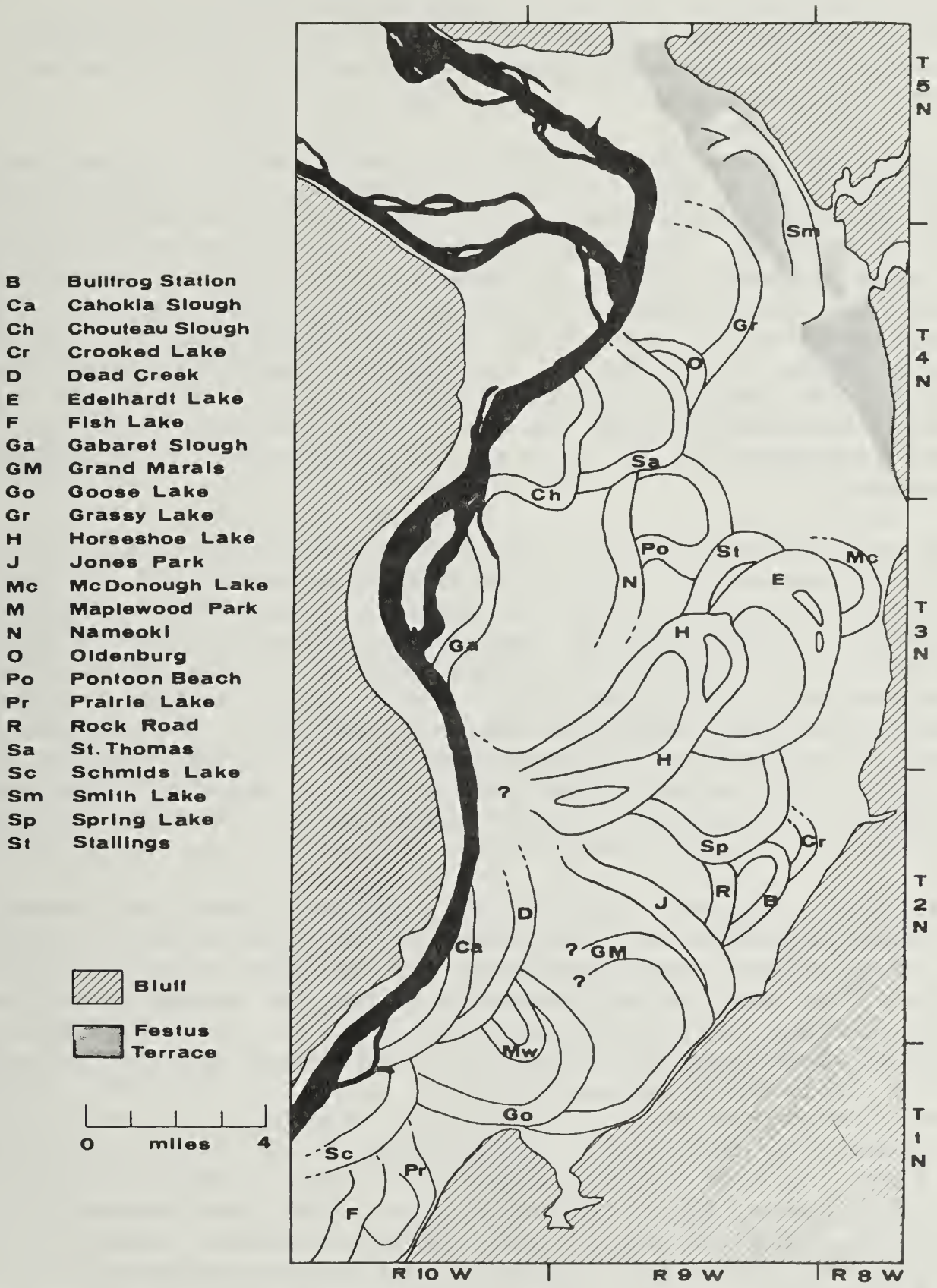

Fig. 1: Terraces and meander loops of the American Bottoms

superimposed upon by the Edelhardt Lake meander and also has a cut-off date prior to 2800 B.P., as determined by the Late Archaic Bullfrog Station site (Ms-45) located adjacent the outside margin of the Spring Lake meander.

In the northern portion of the Bottoms, the St. Thomas meander segment has been determined to have a pre-1600 B.P. cut-off date on the basis of two Middle Woodland sites located immediately adjacent its outside bank: Sunny Acres (Ms-43) and West mound (Ms-76). The Grassy Lake meander, which is superimposed upon by the Oldenberg meander, which in turn is superimposed upon by the St. Thomas segment, may represent a relatively very ancient channel; the Middle Archaic South Roxana site (Ms-66) is located immediately adjacent its outside margin, suggesting a cut-off prior to 5000 B.P. However, as previously noted, this site is upon the flank of the Festus Terrace, and consequently it is possible that it does not relate to this meander.

In the southern portion of the Bottoms a cut-off date prior to 1100 B.P. is suggested for the Goose Lake meander since the Initial Late Woodland Julien site (S-63) is located immediately adjacent its inside bank. Goose Lake in turn is superimposed upon the Grand Marais meander, which had to have been cut-off prior to 1600 B.P. since two sites with Middle Woodland components, Lalumier (S-54) and Lohmann (S-75), are found immediately adjacent its inside bank. The Fish Lake meander, the southernmost channel segment under consideration here, has been determined to have a pre-2800 B.P. cut-off on the basis of the Late Archaic component of the Divers site (Mo-28), which is located immediately adjacent its outside margin.

Utilizing the minimal date of cut-off for these ten channel segments, plus the relative chronology derived from the superimposition of segments, some estimate can be made for the minimal date of cut-off of most of the remaining meander segments within the American Bottoms. In the following listing, meanders with minimal cut-off dates as determined by associated archaeological sites will be followed by those "dates"; e.g., if the cut-off of Meander X pre-dates the end of the Middle Woodland Period it will be indicated as "pre-1600 B.P." If Meander X is superimposed upon Meander Y, then the cut-off of Meander Y, even in absence of known associated archaeological sites as old or older than the Middle Woodland Period, must pre-date 1600 B.P. by at least whatever length of time was necessary for Meander X to form and subsequently to be cut-off. This necessarily greater age for Meander Y will be indicated by a plus sign following the minimal date assigned to Meander X (i.e. pre-1600+ B.P.), and if Meander Y in turn is superimposed on the still older Meander Z, which also lacks known associated archaeological sites, its "date" would be indicated as pre-1600++ B.P. Utilizing these designations, the chronology of cut-off for the channel segments, from latest to earliest, is as follows:

Meander Segment	Cut-Off (B.P.)
Cahokia Slough	pre-275
Choutou-Gabaret-Dead Cr.	pre-275+
Horseshoe Lake	pre-900
Goose Lake	pre-1100
St. Thomas	pre-1600
Grand Marais	pre-1600
Oldenberg	pre-1600+
Nameoki	pre-1600+
Edelhardt Lake	pre-2200
Stallings	pre-2200+
Pontoon Beach	pre-2200++
McDonough Lake	pre-2800
Spring Lake-Jones Park	pre-2800
Fish Lake	pre-2800
Rock Road	pre-2800+
Prairie Lake	pre-2800+
Bullfrog Station	pre-2800++
Crooked Lake	pre-2800+++
Grassy Lake	pre-5000 ?

The Schmids Lake and Maplewood Park meanders are omitted from the above listing since it has not been possible to determine their temporal positions relative to each other or relative to the Horseshoe Lake meander. Both, however, postdate the Goose Lake meander and both pre-date either Cahokia Slough or Dead Creek. The Smith Lake meander is also omitted from this listing since it is a feature associated with Festus Terrace rather than the floodplain.

A final comment concerns two instances where there exist sequences of seven superimposed channels or channel remnants, the youngest being the present channel and the oldest pre-dating 2800 B.P.: 1) present channel to Jones Park, and 2) present channel to McDonough Lake. Assuming that the Jones Park and McDonough Lake meanders were cut off only shortly prior to 2800 B.P., this would indicate an average of 350 years or more between channel changes.

SUMMARY

Archaeological data indicate that final deposition of the Festus Terrace post-dates the end of the Clovis Period (ca. 10,000 B.P.), but that formation had ceased before the end-date of the Dalton point utilization (ca. 9000-8500 B.P.). The same methodology suggests that the surface of the floodplain, at least in general, post-dates the end of the Middle Archaic Period (ca. 5000 B.P.), but that the surface was in existence some years prior to the end of the Late Archaic Period (ca. 2800 B.P.). The 24 meander loop remnants found within the floodplain of the American Bottoms represent segments of at least nine former river channels, and the relationships of archaeological sites to these channels indicate minimal cut-off dates extending back, in some cases, to well prior to 2800 B.P.

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A CRANIUM OF SYMBOS CAVIFRONS (MAMMALIA) FROM THE MISSISSIPPI RIVER BETWEEN SOUTHERN ILLINOIS AND MISSOURI

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ABSTRACT. -- Description and discussion of the cranium and the endocranial cast are presented with speculation that the remains came from Wisconsinan deposits in Illinois. The cranial cast has a distinctive shape, possibly associated with structural support for the horns, that may be of taxonomic value or of use in identifying male and female individuals.

Remains of Symbos cavifrons (Leidy) are not rare but each discovery of a specimen adds to our fund of knowledge concerning the species. In the fall of 1973 Randall Morgan, of Cape Girardeau, Missouri, presented a cranium to the Earth Science Department of Southeast State Missouri University.

Provenance and Age of Specimen

The specimen was recovered during dredging operations a few miles south of Grand Tower, Illinois. Examination of the anterior end of the cranium suggests that a more complete skull had been buried and that little abrasive action had taken place after disturbance and before recovery. I regard this as evidence that the cranium was not moved far from the place of preservation.

Some of the indurated matrix from a diploic sinus was sent to the Illinois State Geological Survey for evaluation. The material proved to be principally siderite with some quartz and traces of other substances. No clay was found. Sedimentary siderites are precipitated by the action, in the absence of oxygen, of organic matter upon a bicarbonate solution of ferrous iron. This is a process similar to the formation of bog iron ore; therefore, I think it is possible that the skull had been buried in a marsh or bog. The nature of the Mississippi valley in this area, with the main channel next to the bluffs of Missouri and a broad flood plain to the east, suggests burial on the Illinois side of the river.

With our knowledge of the geological age of other discoveries of Symbos cavifrons and the circumstances of the discovery reported here, it is probable that the age is Wisconsinan.

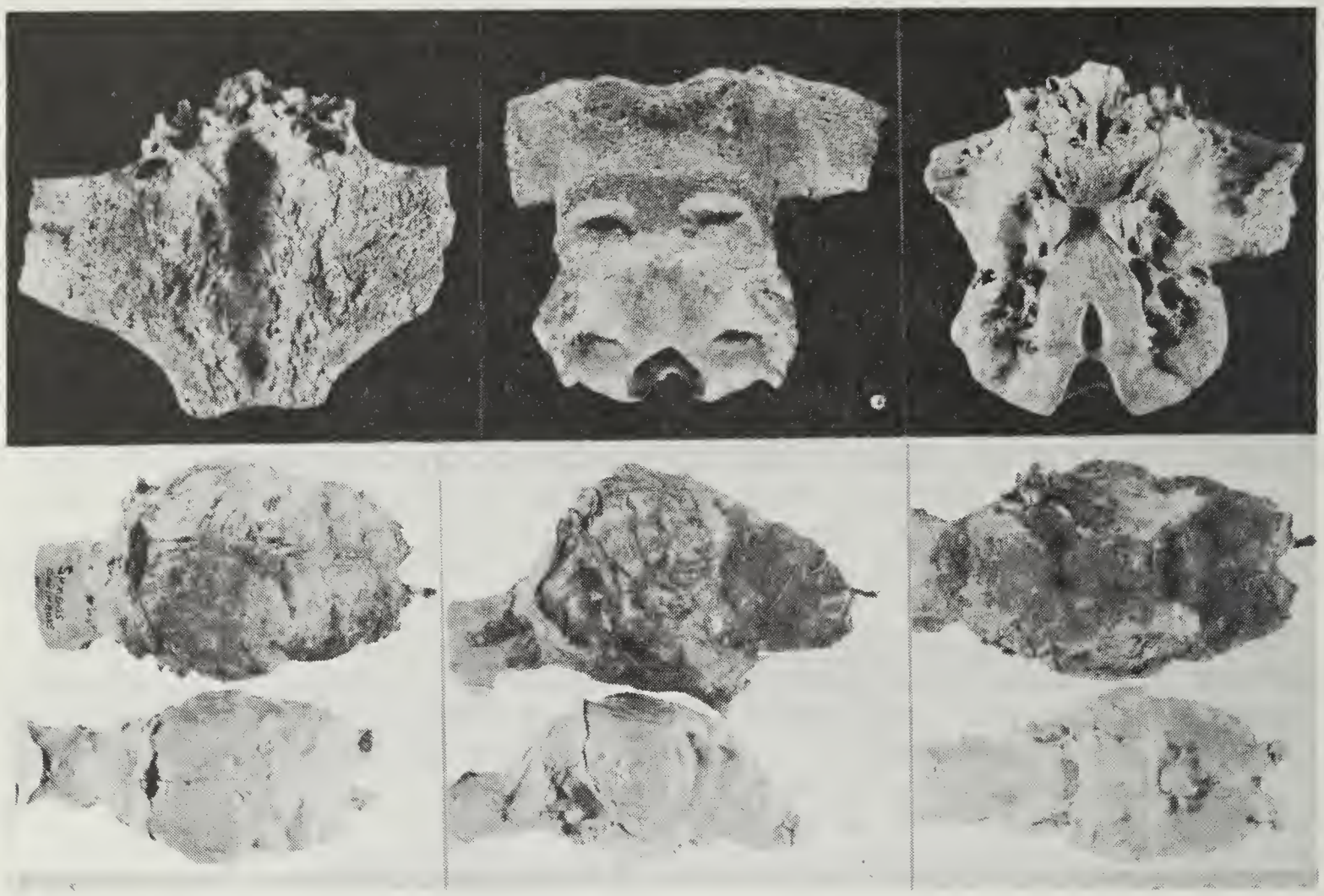

Figure 1. Top: dorsal, posterior and ventral views of the cranium of Symbos cavifrons dredged from the Mississippi River south of Grand Tower, Illinois. Middle: dorsal, lateral and ventral views of the endocranial cast of the specimen figured above. Bottom: dorsal, lateral and ventral views of the endocranial cast of Ovibos moschatus (female) No. 49314, Field Museum of Natural History, Chicago.

Description of Specimen

This specimen consists of the rear part of an adult skull (Fig. 1) broken from the front part at a point anterior to the horn cores and posterior to the orbits. Dimensions least affected by abrasion are:

Depth of skull from bottom of occipital condyles to top of exostosis, 228 mm.
Breadth from lateral surface of right mastoid to midline of skull, 102 mm.
Breadth of occipital condyles, 120 mm.
Breadth of basioccipital at posterior margin, 68 mm.
Width at ventral tips of post-glenoid processes, 110 mm.
Width of left horn core at a point 20 mm lateral to the protruding ledge of the parietal overhanging the fossa for the temporal muscle and perpendicular to axis of the horn at this point, 112 mm.
Depth of horn core in the plane described for the width, 77 mm.

Endocranial Cast

The cast bears a certain similarity to that of a female Ovibos moschatus (Zimmerman), the living musk ox. On the other hand, the cerebrum is relatively higher and wider in Symbos and the dorsal surface is more acutely curved in the tranverse plane. The cerebellum of Symbos is relatively shorter than the cerebrum when compared to the lengths of these parts in Ovibos. Furthermore the almost flat dorsal surface of the cerebellum in Symbos is strikingly different from the cerebellum of Ovibos (female) which has the dorsal surface arched in a manner that can be described as a median ridge. The resulting "peaked" shape of the endocranial cast of Symbos is unlike the shape of any artiodactyl brain figured in Brauer and Schober (1970) or endocranial casts of other artiodactyls seen by me. Some features are not readily displayed in Figure 2. The pons in Symbos is more rounded and swollen ventrally than in Ovibos (female). Equally undetectable is the indication that the facial nerves of Symbos arose from a point posterior to a transverse line marking the rear margin of the pons.

Discussion

I am not aware of any other endocranial cast of Symbos cavifrons, so I shall regard this cast to represent a normal condition worthy of attention.

I think it is a reasonable assumption that the unusual shape of the brain case reflects a relationship between the deep and relatively narrow cranium, the presence of the extensive exostosis on top of the skull, and the large horns but I realize that the relationship must be consistent with the evidence found in other specimens of S. cavifrons and in other species of musk oxen.

Enthusiasm causes me to wonder if the gross shape of the brain case could be a character of taxonomic value or, possibly, a feature that could be correlated with individual age and/or differences due to the sex of the individuals assigned to Symbos and Bootherium. See Semken, et al. (1964) for comments on some of these questions. For example, the specimens of Symbos tyrrelli (Osgood) from Alaska and the specimen from Nebraska assigned to S. tyrelli by Cook (1931, p. 278) would be a fit subject for investigation -- particularly since Hay (1914, p. 304) thought the type specimen to be a female S. cavifrons. The enigmatic Bootherium sargenti Gidley, even if a victim of hormonal imbalance, would yield some evidence on the shape of the brain case. The problem of recognizing the females of S. cavifrons is aggravating and, by any standard, can be described as a case of too many bulls and too few cows; I do not know if the shape of the brain case will resolve this problem but it might eliminate some species from further consideration.

Regardless of the merits of my speculations, the brain case

of Symbos cavifrons reveals an interesting field for research. Such a program is beyond my facilities but I urge its pursuit.

Acknowledgements

Dr. Louis Unfer Jr., Earth Science Department, Southeast Missouri State University permitted me to study this specimen. Drs. John C. Frye and Herbert D. Glass of the Illinois State Geological Survey aided me with advice and the services of their laboratories. Mr. Orville Gilpin of the Field Museum of Natural History, Chicago, had the endocranial cast of Ovibos moschatus prepared for my use. The Zoology Department, Southern Illinois University, provided funds and other support for the study. I am grateful to each for their help.

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REPRODUCTIVE POTENTIAL OF YOUNG-OF-THE-YEAR THREADFIN SHAD (DOROSOMA PETENENSE) IN SOUTHERN ILLINOIS LAKES[1/]

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ABSTRACT

Young-of-the-year threadfin shad (Dorosoma petenense) spawned in southern Illinois waters. The management potential of this fish is discussed.

INTRODUCTION

Researchers have repeatedly demonstrated that the threadfin shad (Dorosoma petenense) is a valuable forage fish (Myhr, 1971; Range, 1971; Beers and McConnell, 1966; Goodson, 1965; Stevens, 1959). Reservoir investigations throughout the southern half of the United States have resulted in recommendations for stocking the threadfin shad where slow-growing crappie (Pomoxis sp.) populations exist (Goodson, 1966). The establishment of threadfin shad populations has also increased the growth rate of white bass (Morone chrysops) and walleye (Stizostedion vitreum) (Range, 1971). In Illinois waters the threadfin shad occurs naturally in the Ohio and Mississippi River drainages during the summer and fall months. The threadfin shad's inability to overwinter in northern waters has previously discouraged interest in their introduction into Illinois lakes. The development of a significant forage population by annual stocking of 2 to 12 adult fish per ha in the spring is partially dependent upon whether or not the young-of-the-year fish will spawn the year in which they are stocked.

The objective of this study was to determine if young-of-the-year threadfin shad could spawn in southern Illinois lakes.

1/ In part this paper is based on a master's research report submitted by the junior author to the Graduate Faculty of Southern Illinois University at Carbondale in 1974. The study was supported by the Graduate School, SIU-C, and the Lake of Egypt Property Owners' Association. Permission to work on Little Grassy Lake was granted by the Crab Orchard National Wildlife Refuge.

MATERIALS AND METHODS

In June 1973, young-of-the-year threadfin shad which were spawned in May were stocked into 10 .06-ha hatchery ponds at a rate of 20 fish per pond. At stocking the fish were 2.53 cm total length. The ponds had a minimum depth of 1 m and a maximum depth of 1.5 m. The ponds contained various combinations and numbers of catfish, sunfish, minnows, and largemouth bass (Micropterus salmoides). Success of reproduction of the young-of-the-year threadfin shad that had been stocked was evaluated by seining on 27 September 1973.

In a second experiment the ability of young-of-the-year threadfin to spawn in a large reservoir was evaluated. In March 1973 approximately 1500 yearling threadfin shad were stocked into Little Grassy Lake. Little Grassy Lake is a 405-ha manmade lake on the Crab Orchard National Wildlife Refuge in Williamson County, Illinois. It has 45 km of shoreline, an average depth of 8 m and a maximum depth of 24 m. The lake has a strong white crappie (Pomoxis annularis) and largemouth bass population. During 1970 a 6-month creel census revealed that the white crappie represented 70.4% of the total catch by weight. The largemouth bass ranked second, constituting 15.2% by numbers and 38.0% by weight (Harrison, 1970). Gizzard shad (Dorosoma cepedianum) also occur in Grassy Lake.

Samples of larval and juvenile threadfin shad were periodically collected from June until November 21, 1973 with a meter net having a mesh size of 0.75 cm. Gill nets of 12.65 mm (1/2-inch), and 18.98 (3/4-inch) bar mesh were used to collect young-of-the-year shad that were not vulnerable to the meter net.

In order to determine if these fish were sexually maturing in Little Grassy Lake, diameters of their ova were measured to the nearest 0.01 mm using a compound microscope at 35x fitted with an ocular micrometer. Ova having diameters greater than 0.53 mm were considered mature (Kilambi and Baglin, 1969). The maturity index (Johnson, 1971), which is equivalent to the gonadalsomatic index (Kilambi and Baglin, 1969), was also calculated on young-of-the-year female threadfin shad using the following formula:

$$\text{Gonadalsomatic index} = \text{maturity index} = \frac{\text{ovary wt. (g)} \times 100}{\text{gross body wt. (g)}}$$

RESULTS

When the 10 hatchery ponds that were stocked in June with young-of-the-year threadfin shad were seined 27 September 1973, 6 ponds contained at least 500 threadfin shad. Two ponds contained only 1 and 6 respectively of the originally stocked young-of-the-year threadfin shad, and 2 ponds contained no shad.

Meter net samples from Little Grassy Lake during June yielded threadfin shad with maximum total length of 38 mm. Gizzard shad were more abundant in the samples throughout June. By mid-July the threadfin shad were predominant over the gizzard shad in numbers collected. On 31 July, gizzard shad disappeared from the meter net samples, whereas threadfin shad on this date were abundant and ranged in total length from 16 mm to 36 mm (Table 1). On the same date, 12.65 bar mesh gill net samples contained threadfin shad that ranged in total length from 81 mm to 93 mm. Thus by 31 July 1973, young-of-the-year threadfin shad, ranging from at least 16 mm to 93 mm in total length, were present in Little Grassy Lake.

Mature ova were present in young-of-the-year threadfin shad by late summer (Table 2), the gonadalsomatic index of young-of-the-year females was at a maximum in July and August and dropped to an insignificant percentage by September. The disappearance of mature ova coincided with the decrease in gonadalsomatic index. Male young-of-the-year threadfin shad were "running ripe" in August.

TABLE 1. Occurrence of threadfin shad and gizzard shad captured in meter net samples from Little Grassy Lake during the summer of 1973.

Month	Total length (mm)		
	0-19	21-29	30-39
June	GT	GT	GT
July	GT	GT	GT
August	T	T	T
September	T	T	--

G = gizzard shad, T = threadfin shad

TABLE 2. Spawning condition of young-of-the-year female threadfin shad in Little Grassy Lake during 1973.

Date	Number of fish	Total length (mm)	Weight (g)	Gonadal-somatic index	Mature ova >0.53 mm
July 31	16	88	7.5	9.6	present
Aug 24	1	92	8.0	8.8	present
Aug 24	3	88	7.0	<1.0	absent
Sept 10	4	98	9.7	<1.0	absent
Nov 21	5	132	21.0	<1.0	absent

DISCUSSION.

A population of young-of-the-year threadfin shad was established in Little Grassy Lake. Based on the length of the threadfin shad in the June samples and assuming that the young-of-the-year threadfin grew at a rate of 20 mm to 24 mm per month (Kersch, 1970), the brood fish commenced spawning in early May. Spawning also took place in May in the small hatchery ponds. The presence of larval and juvenile threadfin shad throughout June and July suggests a prolonged, or a multiple spawning season by the brood stock.

Based on ova diameter, young-of-the-year female threadfin shad were capable of producing mature ova in less than 4 months after hatching in Little Grassy Lake. However, Johnson (1971) stated that female threadfin shad with a maturity index of less than 19% were incapable of releasing eggs, even though mature ova may be present in fish with a lower maturity index. He measured fish 2 years of age and older. Kilambi and Baglin (1969) considered females with a gonadalsomatic index of 14% to be mature. They, too, considered only fish 2 years or older.

The gonadalsomatic index of young-of-the-year threadfin shad collected from Little Grassy Lake was lower than the gonadalsomatic index considered as mature by the above authors. There are at least three plausible explanations for this difference. The gonadalsomatic index could have exceeded 14% during the 3 weeks between collections. Size selectivity of the 12.65 mm gill net may have accounted for the scarcity of the more robust females. Finally, fish in this study were young-of-the-year, and the gonadalsomatic index of threadfin shad probably increases with age and size.

It is possible that the larval threadfin shad collected with the meter net from Little Grassy Lake in August and September could have resulted from a second spawn of the adult brood stock. Regardless, based upon the facts that young-of-the-year fish spawned in the hatchery ponds; mature ova were present in young-of-the-year females before and during August, but not afterwards; and young-of-the-year males were running ripe in August, it appears that young-of-the-year threadfin shad spawned in Little Grassy Lake.

Since the young-of-the-year threadfin shad spawn in southern Illinois waters, an arithmetic increase in the density of the brood stock can result in a geometric increase in the forage produced. Consequently, there is a considerable potential for this management technique in midwestern lakes.

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DISTRIBUTION OF THE COMMON VASCULAR HYDROPHYTES IN ILLINOIS

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ABSTRACT.-- The investigation of numerous aquatic habitats has extended the ranges of many hydrophytes in Illinois. Notes concerning the geographic distribution and county distribution maps of these species are included.

Aquatic plants have not been commonly collected in Illinois until fairly recently. Therefore, for many taxa, the counties for which the species have been reported by Jones and Fuller (1955), Winterringer and Evers (1960) and more recently by Mohlenbrock (1967a,1970) represent an incomplete picture of their distribution in the state. Because of this, the authors investigated aquatic habitats for the past four years in an attempt to update and to extend the distributional ranges of vascular hydrophytes in Illinois.

Besides the authors' collections, numerous specimens from most of the herbaria in the state were examined. The most extensive collection is at the Illinois State Museum (ISM). Most of these specimens had been collected during the summers of 1964 and 1965 by Conservation Biologists of the Division of Fisheries, Department of Conservation. A total of 1175 collections had been made by these Conservation Biologists who were involved in a project to collect and identify the submersed and floating aquatic plants of the state of Illinois. The most extensive collections were made by K. Russell, A. W. Fritz, R. Fisher, and J. Allen. A description of the project and its accomplishments are discussed by Lopinot (1965) and Winterringer (1966).

The present literature concerning the distribution of aquatic vascular plants in Illinois is fairly extensive. Recently, Winterringer and Lopinot (1966) completed a flora of the vascular hydrophytes of Illinois but gave only the general distribution of each species in the state. Also, a few families of hydrophytes have been studied in detail. Mohlenbrock and Richardson (1967) revised the Alismales of Illinois, while the Lemnaceae were studied by Weik and Mohlenbrock (1968) and the Haloragaceae and Hippuridaceae were revised by Meyer and Mohlenbrock (1966).

Most of the remaining literature on the aquatic vascular plants are regional studies or reports concerned with new county records. The

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majority of these reports are concerned with the plants of southern Illinois. A detailed discussion of the varied aquatic habitats in southern Illinois is given by Mohlenbrock (1959), and Mohlenbrock, Dillard, and Abney (1961), while Fore, Stookey and Parsons (1965) recorded the distribution of aquatic and shoreline species. Other reports from this area are mostly incidental reports in checklists and notes concerned with county records and range extensions. These reports include a checklist of the Pine Hills Field Station by Ashby and Kelting (1963) and Mohlenbrock and Voight (1965); a study of the Devils Kitchen Area by Mohlenbrock (1962) and Stookey, Fore, and Mohlenbrock (1964); a discussion of the plant communities at Horseshoe Lake by Koelling (1968); a checklist of the plants of Lake Murphysboro State Park by Mohlenbrock (1967b) and a listing of new county records for Washington County by Windler (1966). Range extensions of aquatic species into southern Illinois are listed by Schwegman and Mohlenbrock (1966, 1968). A few aquatic species are also listed by Hopkins (1969) for some fresh-water springs in southern Illinois while Anderson and White (1970) found a few aquatic species in a cypress swamp in Johnson County.

For the remainder of the state, the reports are very meager with only a few species listed in county checklists. For eastern Illinois there are reports by Ebinger (1967) and by Parker, Rayhill, and Ebinger (1969) for Coles County while Wunderlin (1966) lists a few aquatic species from the Mississippi Palisades State Park in western Illinois. Recently, Dolbeare (1974) included a few aquatics in a study of plants collected in western Illinois and Dobbs (1963) included a few in his flora of Henry County. Also, Myers (1972) published a catalog of the Illinois flora and included a few aquatic records for McDonough County. In northeastern Illinois Swink (1969) recorded a few new aquatic records while Dobeare (1967) listed a number of aquatics from Grays Lake in Lake County.

In addition to the above material, the aquatics of strip mines in Illinois have been studies by Bell (1956) and Lewis and Peters (1955). Other contributions include the report of two new species of naiads to the flora of Illinois (Fore and Mohlenbrock, 1966), and the addition of Naias marina L. and Ruppia maritima L. to the Illinois flora by Winterringer (1966).

The annotated checklist which follows contains new county records for many vascular hydrophytes of Illinois. This list is restricted mainly to free-floating, submersed, and floating-leaved hydrophytes. Only a few emergent species are included, and no attempt was made to list the numerous shorleline species. Each species listed is followed by a brief note concerning its habit and distribution in Illinois. Included for most of the species is a county map showing their distribution in Illinois. On these maps a circle represents a county in which the species has been reported previously while a square indicates a new county record. For a few of the rare species, and some for which only a few new records are being reported, no map is included. For these species the county and collecting data of the specimens are listed. The herbaria included in this study are the

Illinois State Museum (ISM), Eastern Illinois University (EIU), the University of Illinois (ILL), the Illinois State Natural History Survey (ILLS), and Western Illinois University (WIU). The nomenclature conforms to Jones (1963).

Marsileaceae

Marsilea quadrifolia L. An emergent, aquatic fern that is rarely found in older ponds and lakes in the southern two-thirds of the state. It is native to Europe and when introduced rapidly becomes established and commonly persists (Ebinger, 1967). It is now well established in ponds at Kickapoo State Park in Vermilion County where it was introduced by the State Natural History Survey in 1939 (Jones and Fuller, 1955).

County records.-- MADISON: Onized Club waters, 2 mi NW of Godfrey, Lockart (14 July 1965) (ISM).

Salviniaceae

Azolla mexicana Presl. This floating fern is relatively common in the western part of the state. No specimens are known from east-central Illinois.

County records.-- JOHNSON: Watson Pond, White 1991 (SIU). MASSAC: Mermet Lake, Ebinger 14843 (EIU).

Acanthaceae

Dianthera americana L. A common emergent that grows in shallow water and on muddy shores of rivers and lakes. It is probably statewide in distribution (Map 1).

Cabombaceae

Brasenia schreberi Gmel. This floating-leaved species is rarely encountered except in scattered localities that are mostly in southern and northeastern Illinois. Very few collections are known from the central part of the state (Map 2).

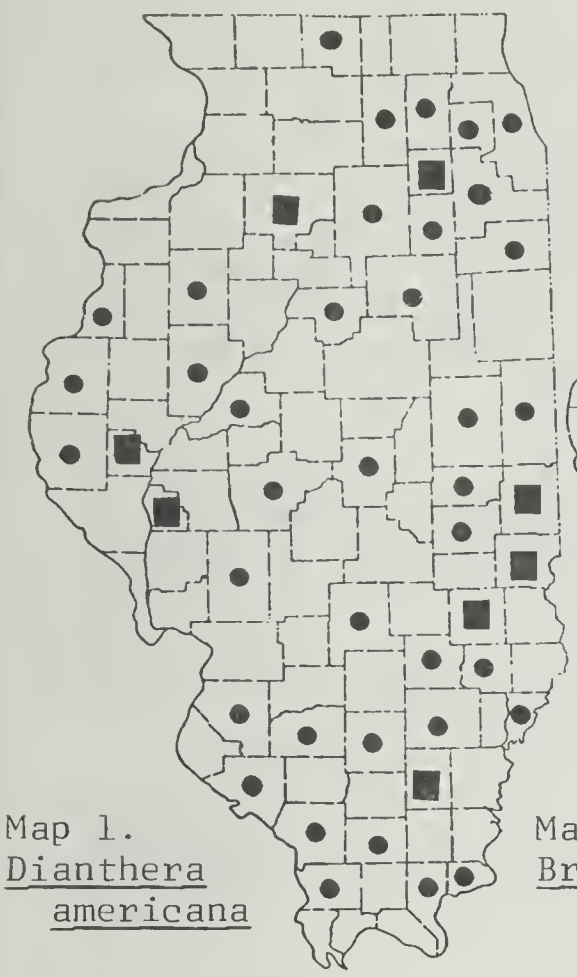
Cabomba caroliniana A. Gray An extremely rare submersed aquatic that is found in ponds and slow-moving streams. Except for its occurrence in Vermilion County it is known from only extreme southern Illinois.

County records.-- JACKSON: Turkey Bayou, NE of Howardton, Evers 104901 (ILLS). SALINE: Marten's Pond, 3 mi NW of Galatia, Allen (17 June 1964) (ISM). VERMILION: Boy Scout Pond, 1 mi SE of Oakwood, Fritz (9 Sept. 1965) (ISM).

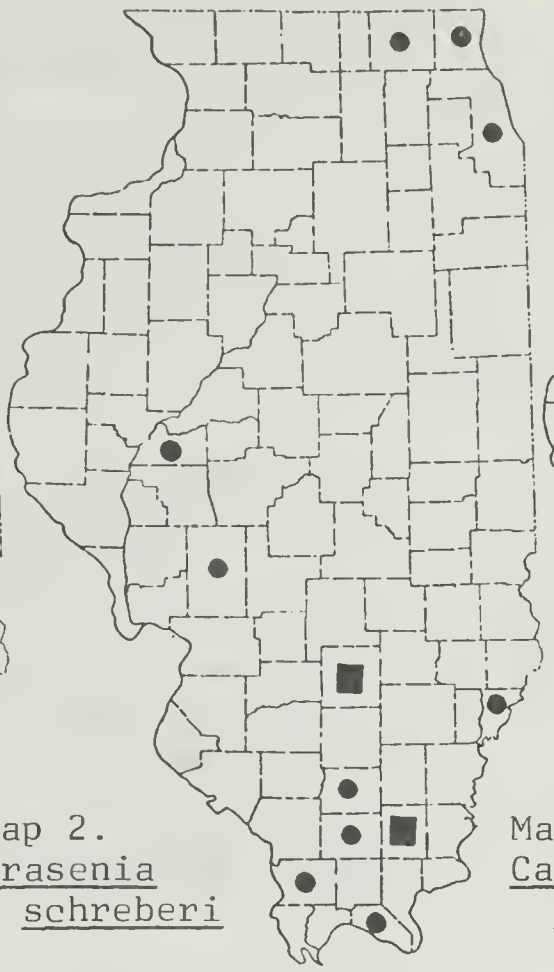
Callitrichaceae

Callitriche heterophylla Pursh This aquatic with submersed and floating leaves is sometimes encountered in ponds. More commonly, we have found it in ephemeral pools and ditches in early spring. It is found scattered throughout the state (Map 3).

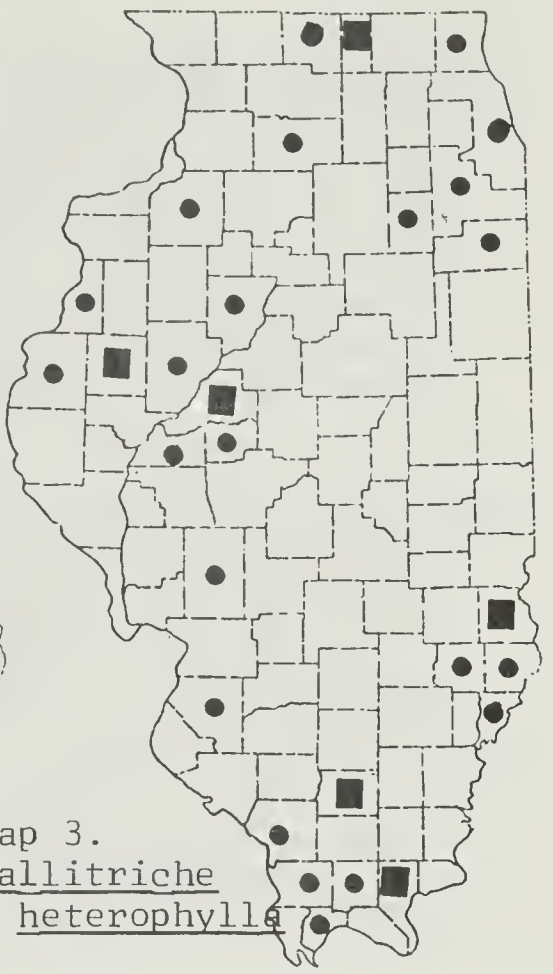
Callitriche palustris L. This taxon is found in scattered localities throughout the state, being more rarely encountered than the preceding species (Map 4). Its ellipsoid, sharply keeled fruits separate it from C. heterophylla which has nearly round fruits that lack keels.



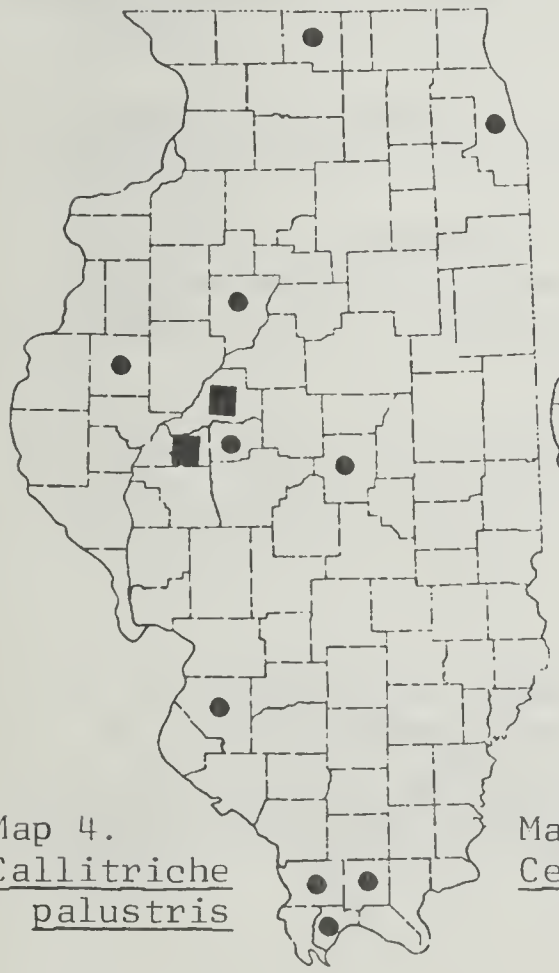
Map 1.
Dianthera
americana



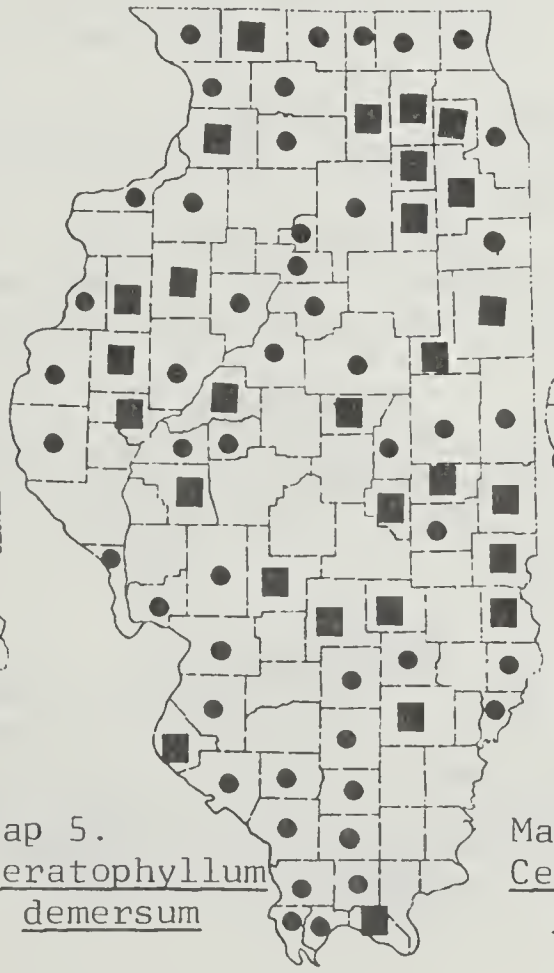
Map 2.
Brasenia
schreberi



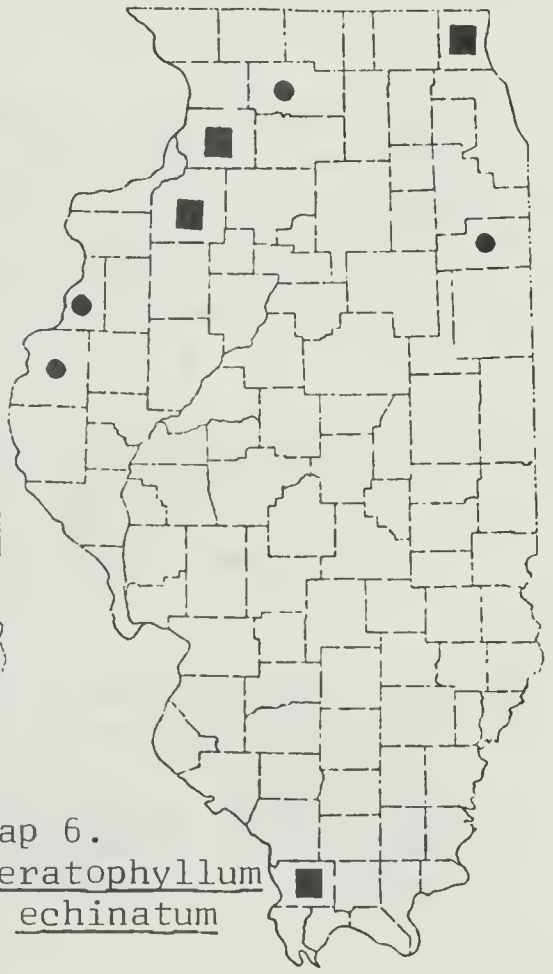
Map 3.
Callitriche
heterophylla



Map 4.
Callitriche
palustris



Map 5.
Ceratophyllum
demersum



Map 6.
Ceratophyllum
echinatum

Ceratophyllaceae

Ceratophyllum demersum L. A fairly common submersed aquatic that is statewide in distribution (Map 5).

Ceratophyllum echinatum A. Gray A relatively rare submersed aquatic that is locally abundant, mostly in the northern part of the state (Map 6). We have found this taxon growing together with C. demersum. When this occurs it is not very abundant and easily overlooked. Fruiting material is necessary for accurate separation of these taxa. The achenes of C. echinatum commonly have 10 or more spines while the achenes of C. demersum have only 3 spines.

Haloragaceae

Myriophyllum pinnatum (Walt.) BSP. This aquatic, which occurs most commonly on mud flats, is found in scattered localities in western and southern Illinois. Vermilion and Richland Counties are the only reports of this species in eastern Illinois.

County records.-- JACKSON: Ditch NE of Gorham, Evers 65707 (ILLS). RICHLAND: Pond, 1 mi E of Calhoun, Ebinger 10775 (EIU).

Myriophyllum spicatum L. A submersed aquatic that is occasionally encountered in older lakes and farm ponds. It is mostly restricted to the northern half of the state (Map 7). This taxon is referred to M. exalbescens Fern. by Winterringer and Lopinot (1966) and Meyer and Mohlenbrock (1966).

Lentibulariaceae

Utricularia gibba L. This submersed aquatic is sometimes found on muddy shores, and usually in semi-stagnant habitats. It is probably restricted to the south, southwest, and northeast parts of the state. No specimens are known from east-central Illinois (Map 8).

Utricularia minor L. An extremely rare, submersed aquatic that has been reported from only two counties in the northeastern corner of Illinois.

County records.-- CLAY: Farm pond, 7 mi NW of Orchardville, Fisher (30 Aug. 1965) (ISM). SALINE: Marten's Pond, 3 mi NW of Galatia, Allen (17 June 1964) (ISM).

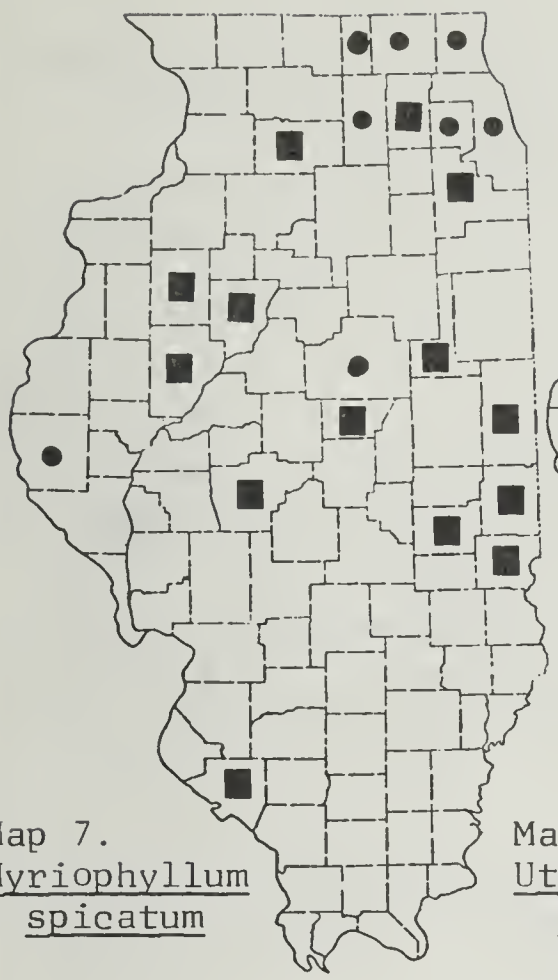
Utricularia vulgaris L. This bladderwort has a sporadic occurrence in the state, being most common in the northern and western parts of Illinois. No specimens are known from east-central Illinois (Map 9).

Lythraceae

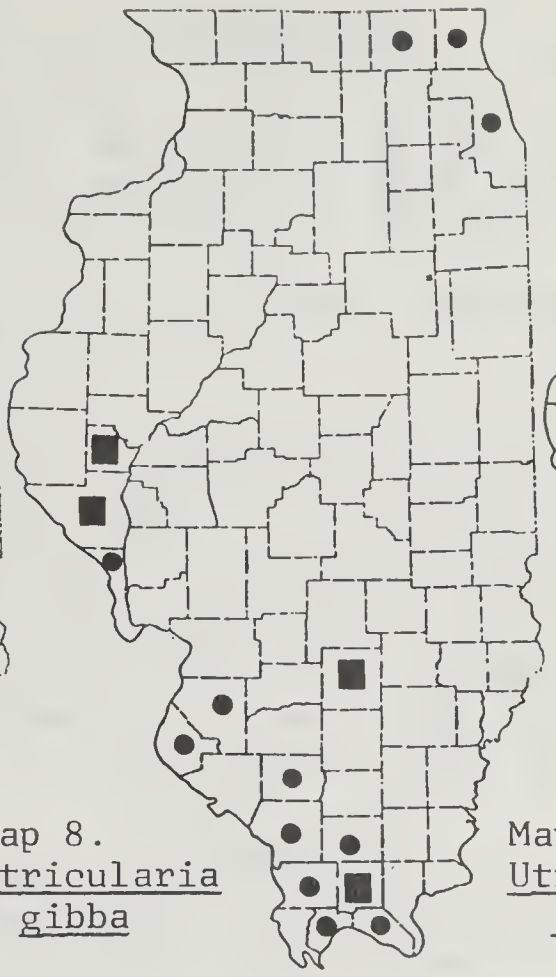
Peplis diandra Nutt. This usually submersed aquatic is rarely encountered. It is found in scattered localities that are mostly in southern and western Illinois. No collections are known from east-central Illinois (Map 10).

Nelumbonaceae

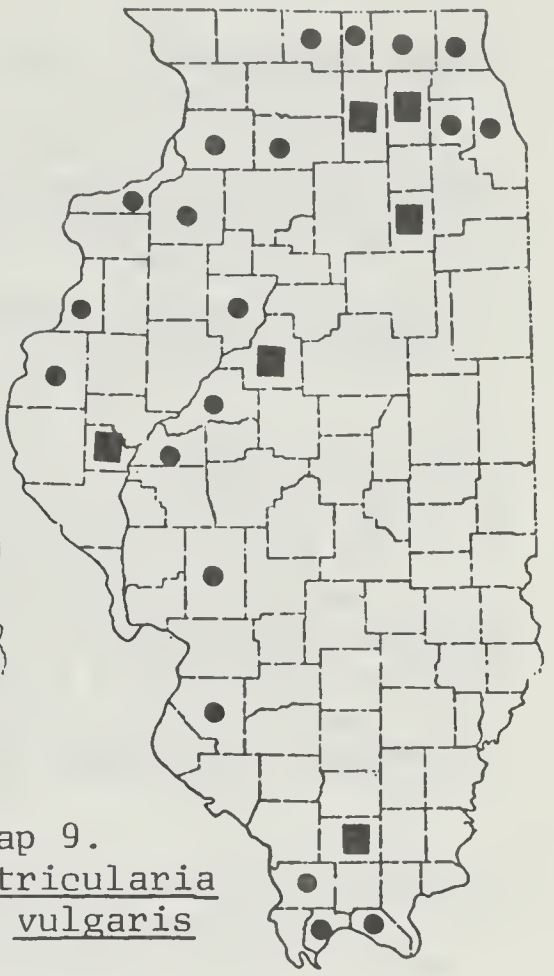
Nelumbo lutea (Willd.) Pers. This extremely beautiful emergent is found in shallow waters of usually older aquatic habitats. It is more common in western and southern Illinois, being reported as abundant along the Mississippi and Illinois Rivers by Winterringer and Lopinot (1966). It is undoubtedly statewide in distribution, probably the result of cultivation (Map 11).



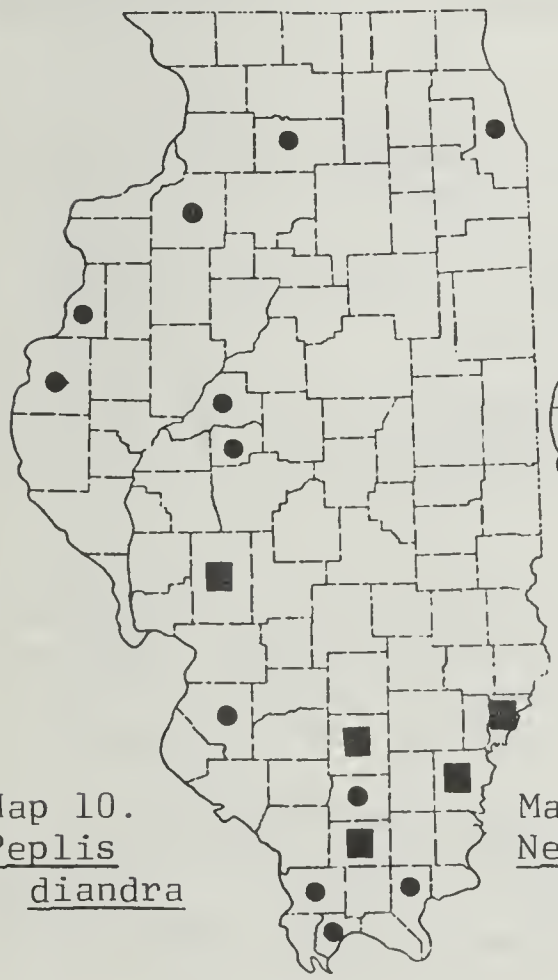
Map 7. *Myriophyllum spicatum*



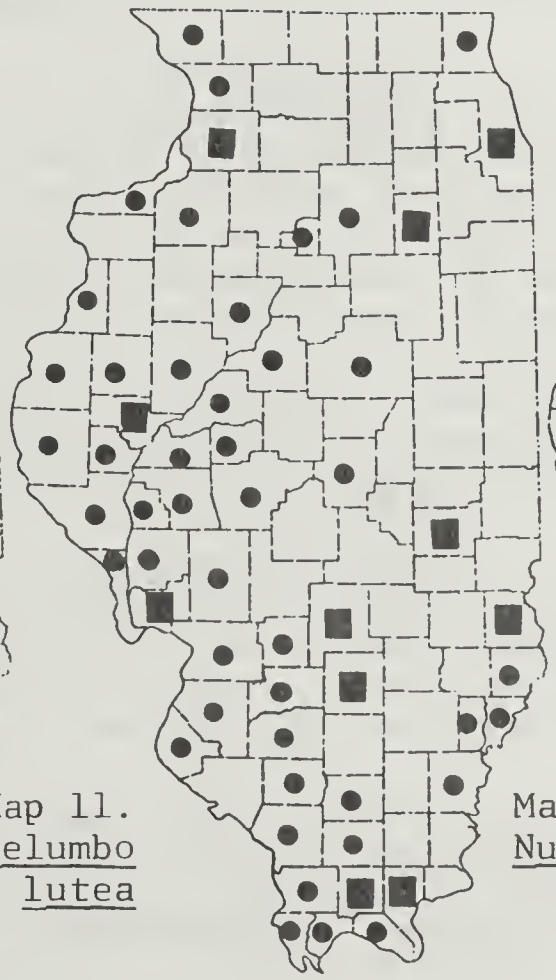
Map 8. *Utricularia gibba*



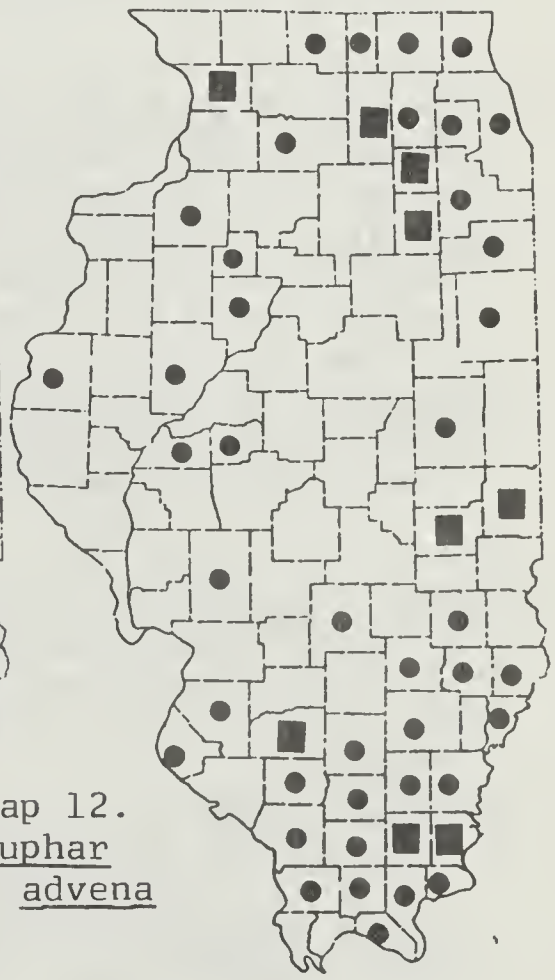
Map 9. *Utricularia vulgaris*



Map 10. *Peplis diandra*



Map 11. *Nelumbo lutea*



Map 12. *Nuphar advena*

Nymphaeaceae

Nuphar advena Ait. This emergent species is statewide in distribution, probably occurring in every county. It is usually restricted to sheltered lake shores and to slow-moving streams (Map 12).

Nuphar variegatum Engelm. This rare emergent is restricted to the extreme northeast corner of the state where it is now known from three counties.

County records.-- MCHENRY: McCullom Lake, 1 mi E of Greenwood, Dolbeare 1198 (EIU).

Onagraceae

Jussiaea repens L. A pantropical, emergent aquatic that is found on muddy banks and shorelines in the southern half of the state (Map 13). It is rare in the rest of Illinois, being extremely uncommon north of the terminal moraine of the Wisconsin glacier.

Ludwigia palustris (L.) Ell. Similar to the preceding species in habitat, but being a smaller plant it is not as obvious. It is very common on moist, muddy shores and is statewide in distribution, probably occurring in every county (Map 14).

Polygonaceae

Polygonum coccineum Muhl. A common emergent that is usually found in shallow water or on wet ground. It is statewide in distribution and probably occurs in every county (Map 15).

Primulaceae

Hottonia inflata Ell. A very rare and unusual aquatic that is sometimes encountered in swamps in extreme southern Illinois.

County records: JOHNSON: Cypress swamp SW of Forman, Evers 98772 (ILLS). POPE: Round Lake, New Liberty, Schwegman (9 May 1970) (ILLS).

Ranunculaceae

Ranunculus flabellaris Raf. A submersed aquatic that is sometimes encountered in ponds and slow-moving streams throughout most of the state. It is more common in northern Illinois (Map 16).

Ranunculus longirostris Godr. This aquatic buttercup is commonly submersed, but sometimes is found on muddy shores. Though not commonly encountered, it is nearly statewide in distribution. It is common in the northern half of the state (Map 17).

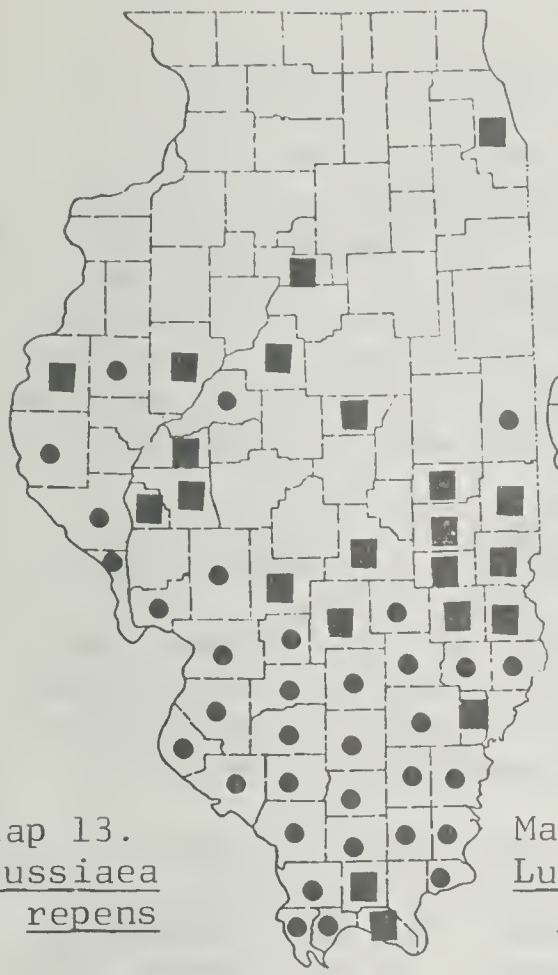
Ranunculus trichophyllus Chaix Similar to the preceding species but with softer, petioled leaves. It is not very common, and is mostly restricted to the northern half of the state (Map 18).

Scrophulariaceae

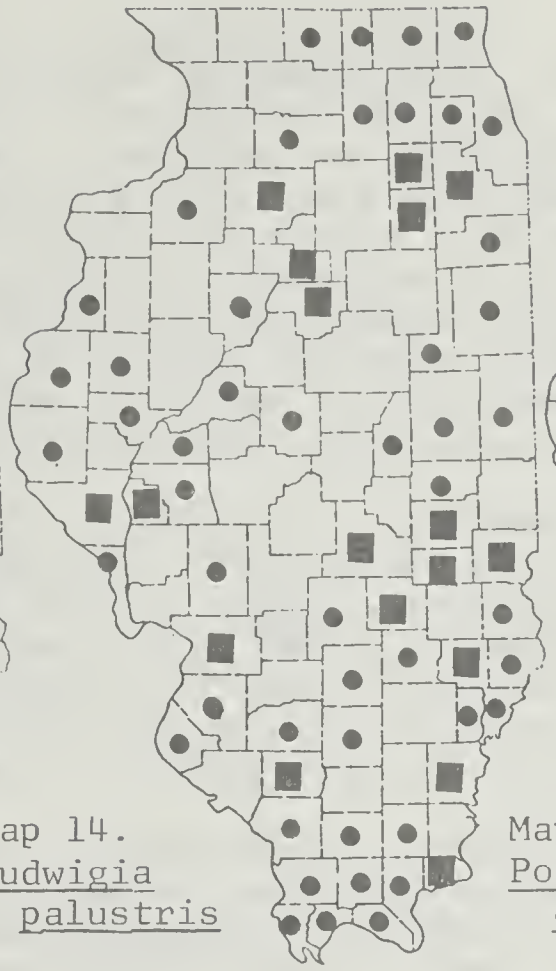
Bacopa rotundifolia (Michx.) Wettst. This species is mostly restricted to muddy shores and very shallow water. It is occasionally found in the southern and western parts of the state and has rarely been reported from north of the terminal moraine of the Wisconsin glacier (Map 19).

Veronica catenata Pennell This emergent species is occasionally encountered in the northern half of the state. The only southern collection is from St. Clair County.

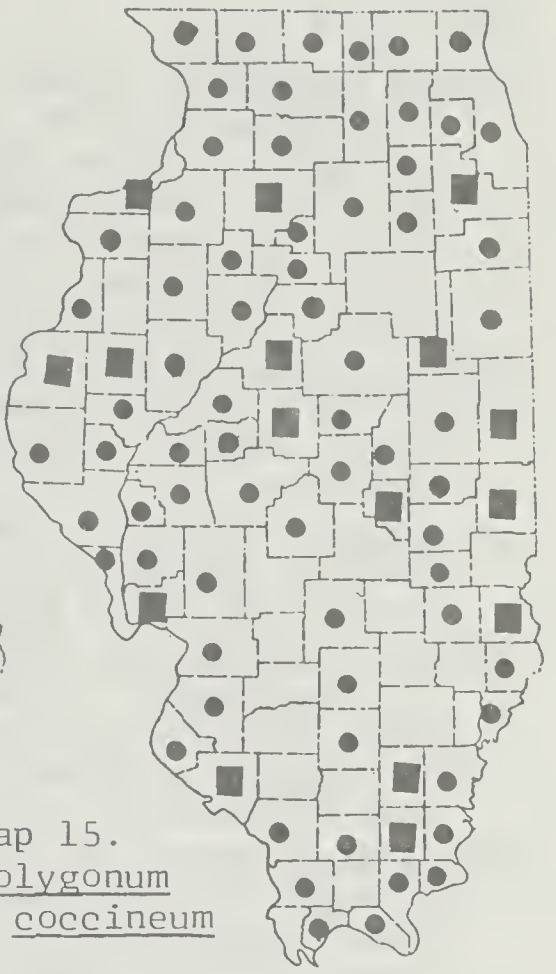
County records.-- VERMILION: Strip mine pond at Kickapoo State Park, Ebinger 11676 (EIU).



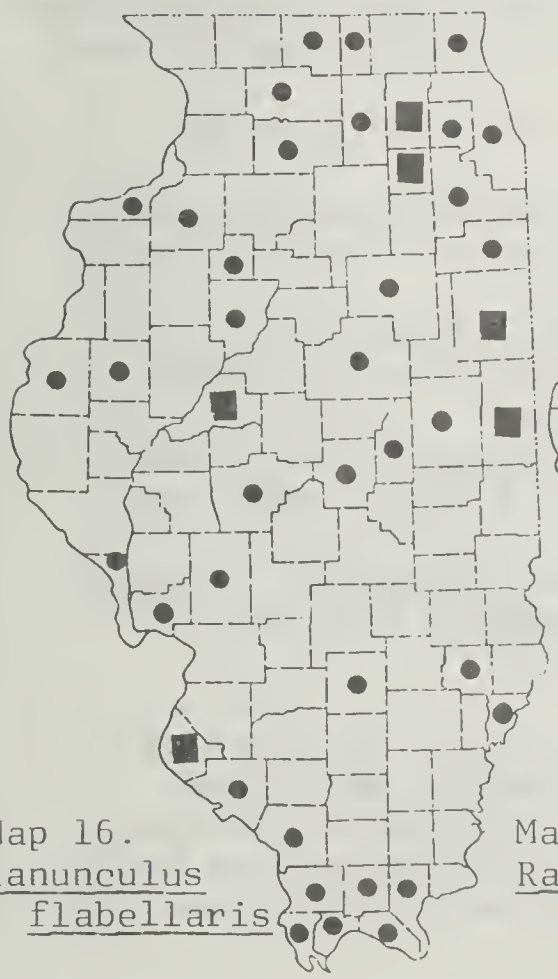
Map 13.
Jussiaea
repens



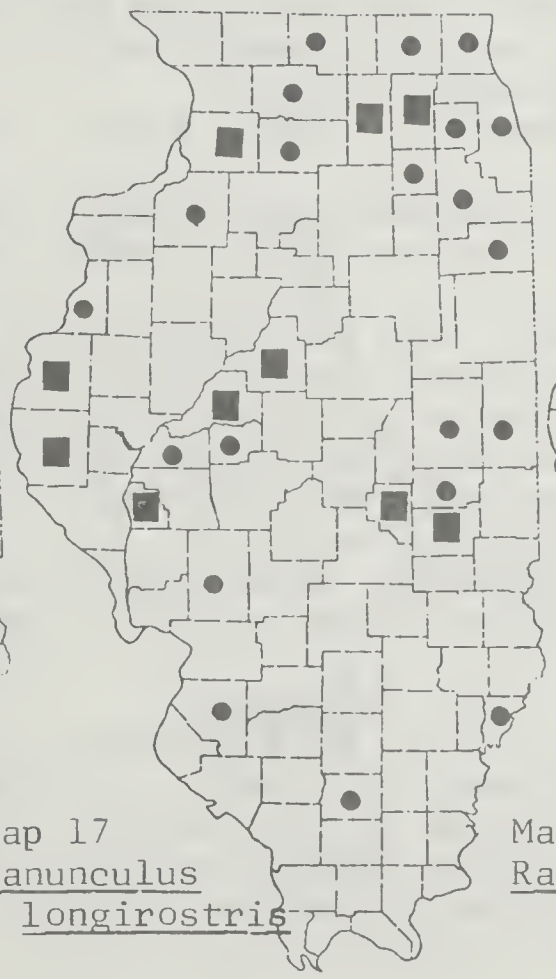
Map 14.
Ludwigia
palustris



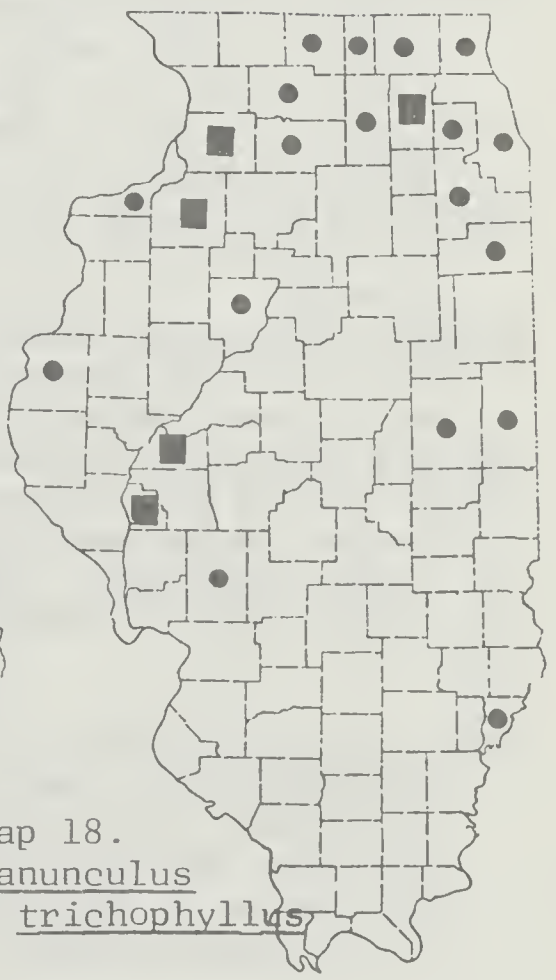
Map 15.
Polygonum
coccineum



Map 16.
Ranunculus
flabellaris



Map 17
Ranunculus
longirostris



Map 18.
Ranunculus
trichophyllus

Hydrocharitaceae

Elodea canadensis Michx. This submersed aquatic is occasionally encountered in older lakes and farm ponds. It occurs very sporadically in southern Illinois, becoming more common farther north (Map 20). This species is similar to E. occidentalis and is sometimes confused with it. Usually the leaves of E. canadensis are wider (1.5-5 mm wide) than those of E. occidentalis (0.5-1.5 mm wide), but for accurate separation flowering material is necessary.

Elodea densa Planch. This submersed aquatic is adventive in Illinois, probably being introduced as a result of aquarium disposals (Mohlenbrock, 1970). It is now known from 4 counties, all in southern Illinois.

County records.-- EDWARDS: Jarvis Oil Co. Lake #2, SE edge of Albion, Fisher (10 July 1964) (ISM). JEFFERSON: Lakeview Estates Lake, 1 mi. W of Mt Vernon, Fisher (17 June 1965) (ISM).

Elodea occidentalis (Pursh) St. John This species is more common than E. canadensis. It is fairly rare in southern Illinois, but becomes much more common farther north (Map 21). This taxon is referred to E. nuttallii (Planch.) St. John by Winterringer and Lopinot (1966) and Mohlenbrock (1970).

Vallisneria americana Michx. An occasionally encountered submersed aquatic that is restricted to the northern half of the state.

County records.-- JO DAVIESS: Perchang's Lake, 1.5 NW of Blanding, Rock (24 Aug. 1965) (ISM). ROCK ISLAND: Gager (10 Aug. 1966) (WIU).

Lemnaceae

Lemna minor L. This extremely common floating species is statewide in distribution. It probably occurs in every county (Map 22).

Spirodela oligorhiza (Kurtz) Hegelm. This extremely rare floating species has been reported from only Union and Alexander Counties. The smaller fronds with usually 3 nerves and 1-5 rootlets make it easy to separate from the next species.

County records.-- LAWRENCE: Pond, 3 mi NE of Lawrenceville. Ebinger 10733 (EIU).

Spirodela polyrhiza (L.) Schleid. This fairly common floating species is statewide in distribution. It probably occurs in every county (Map 23).

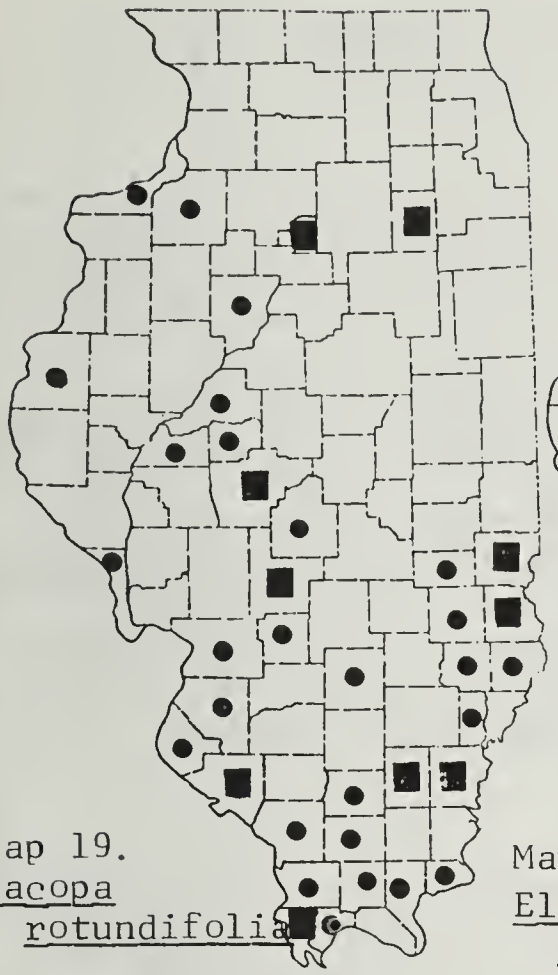
Wolffia columbiana Karst. This extremely small floating aquatic is statewide in distribution. It probably occurs in every county, but may be overlooked because of its size (Map 24).

Wolffia punctata Griseb. This tiny floating species has been found in scattered localities throughout the state. It is probably most common in west-central Illinois.

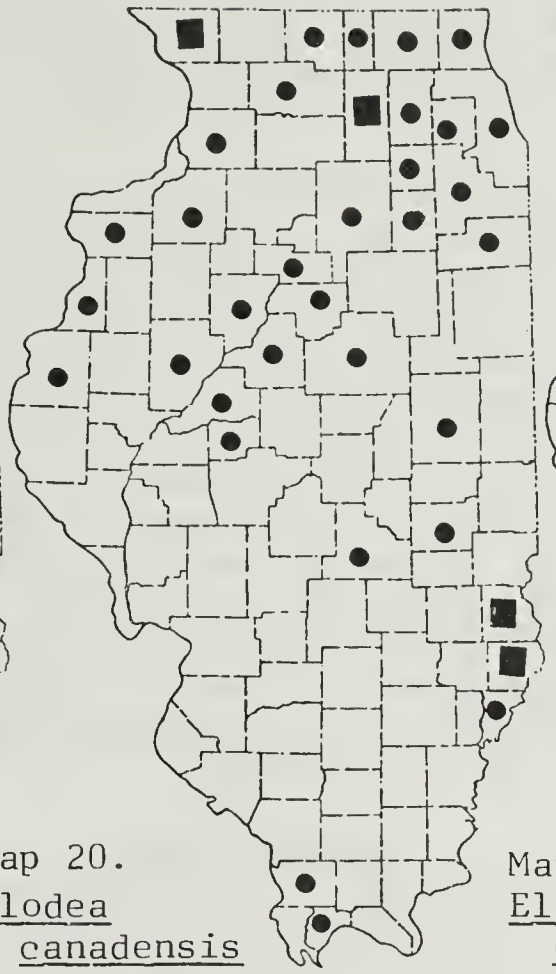
County records.-- RICHLAND: Small lake, 1 mi N of Olney, Ebinger 11913 (EIU). WOODFORD: 7 mi S of Lacon, Hartman 1420 (WIU).

Naiadaceae

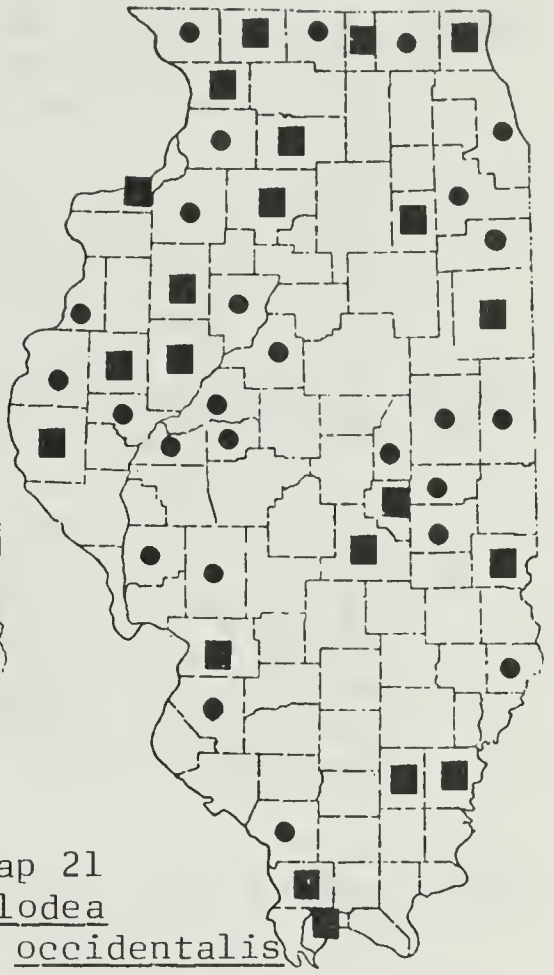
Naias flexilis (Willd.) R.& S. This submersed aquatic is sometimes found in older farm ponds and lakes. It is widely scattered throughout the state, but is more common in northern and western Illinois (Map 25). Dobbs (1963) mentions that this species probably occurs in Henry County, but the specimen was in such poor condition that he could not verify it.



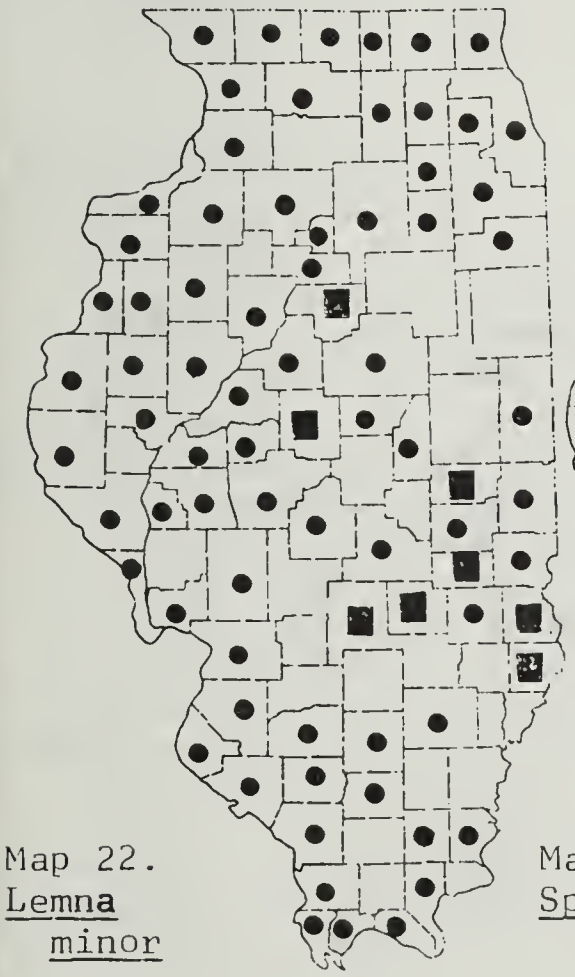
Map 19.
Bacopa
rotundifolia



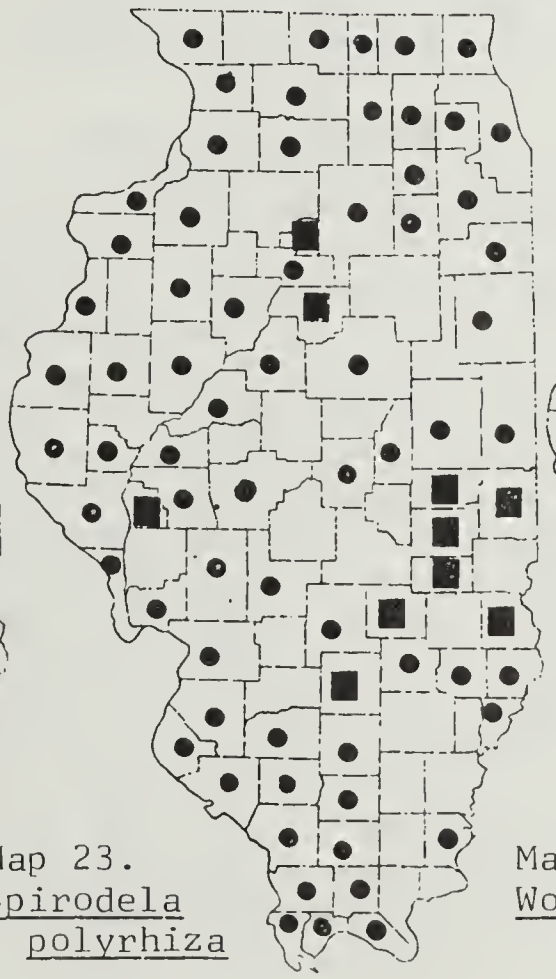
Map 20.
Elodea
canadensis



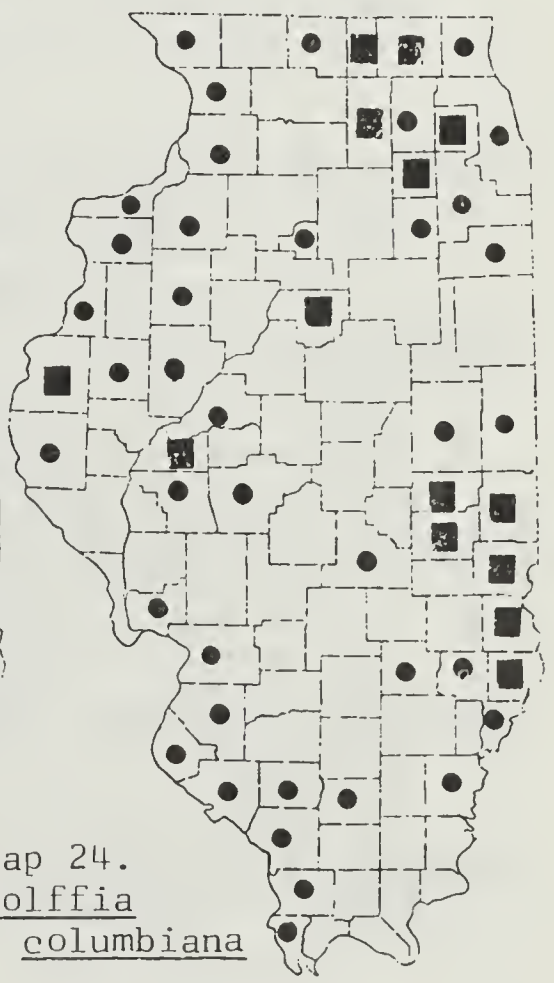
Map 21
Elodea
occidentalis



Map 22.
Lemna
minor



Map 23.
Spirodela
polyrhiza



Map 24.
Wolffia
columbiana

Naias gracillima (A. Br.) Magnus This delicate and slender naiad is rarely encountered. Except for its occurrence in Ford County it appears to be restricted to the southern one-third of Illinois (Map 26).

Naias minor All. This fairly common submersed species which has become naturalized from Europe was not listed by Jones (1963), being first reported for Illinois in 1966 (Fore and Mohlenbrock, 1966; Winterringer, 1966). It is now commonly encountered in older lakes and farm ponds in the southern two-thirds of Illinois (Map 27).

Naias guadalupensis (Spreng.) Magnus This submersed species was reported as rare by Jones (1963) while Mohlenbrock (1970) reported it as "occasional in the southern counties; rare or absent elsewhere." We have found this species to be one of the most common aquatics in the southern two-thirds of the state (Map 28). Naias guadalupensis is similar to N. flexilis and is commonly confused with it. Careful examination of the achenes is necessary to separate these taxa. In N. flexilis the areolae are very small and in 30 to 50 rows on the achene while in N. guadalupensis the areolae are much larger and in only 16 to 24 rows.

Pontederiaceae

Heteranthera dubia (Jacq.) MacM. A submersed aquatic that is occasionally encountered in the northern two-thirds of the state (Map 29). Mohlenbrock (1970) places this taxon in the genus Zosterella.

Heteranthera limosa (Sw.) Willd. This extremely rare aquatic was recently reported from Hardin County (Fore, Stookey, and Parsons, 1965). The present record represents the farthest north that this tropical American species has been reported in Illinois.
County records.-- ADAMS: Fairground pond, Mendon, Henry 1588 (WIU). MASON: Sand pond, west of Saidora, Rexroat 5198 (ISM). UNION: Pond, Union Co. Game Refuge, Ebinger 13141 (EIU).

Potamogetonaceae

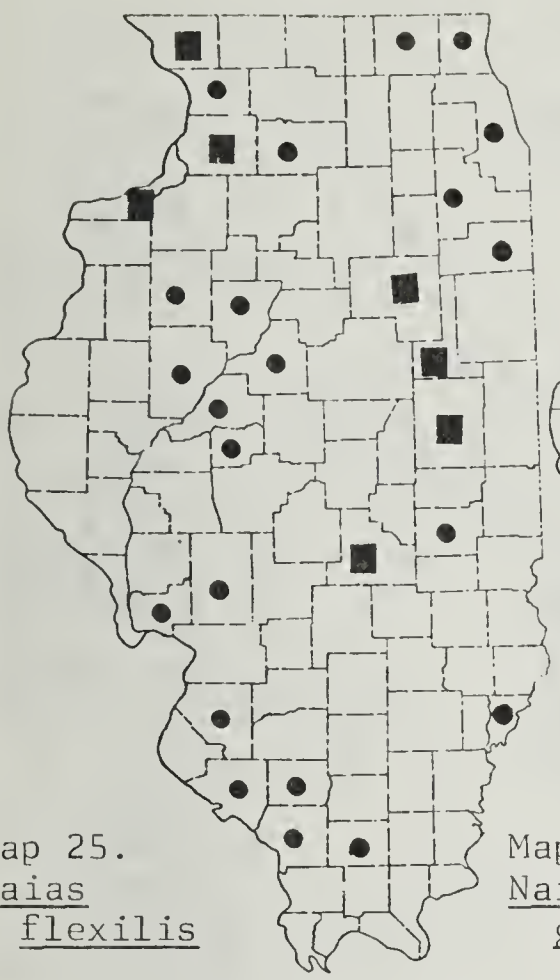
Potamogeton americanus C. & S. This pondweed is commonly encountered in older lakes and ponds throughout Illinois. It probably occurs in every county (Map 30). This taxon is referred to P. nodosus Poir. by Winterringer and Lopinot (1966) and Mohlenbrock (1970).

Potamogeton crispus L. This naturalized, European species has become well established in Illinois. According to Mohlenbrock (1970) it is restricted to the northern half of the state. It now appears to be statewide in distribution, but is more common in northern Illinois (Map 31). We have rarely found fruiting material of this taxon.

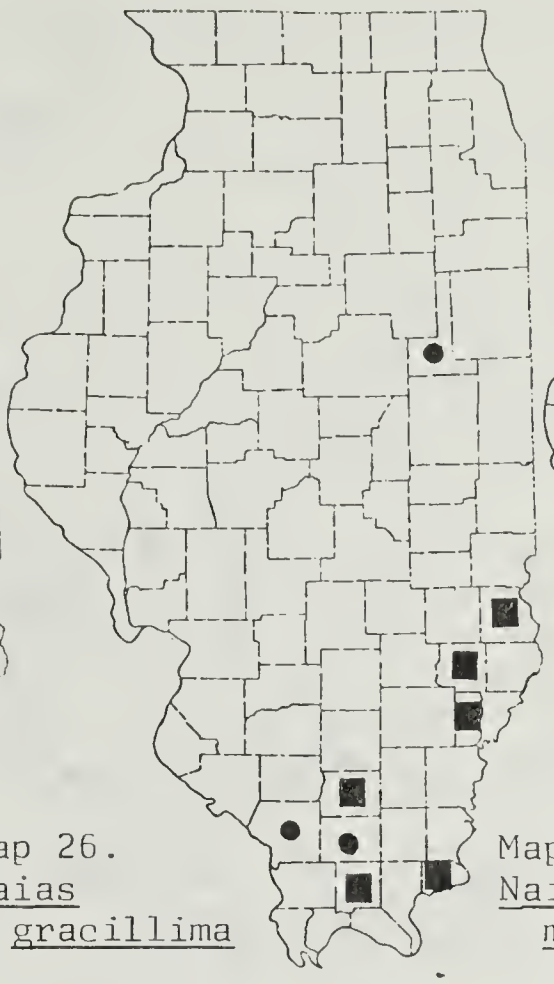
Potamogeton diversifolius Raf. This pondweed is relatively common in southern and western Illinois. Except for its occurrence in the extreme northern counties of Illinois it is not commonly found north of the terminal moraine of the Wisconsin glacier (Map 32).

Potamogeton foliosus Raf. This submersed pondweed is a pioneer aquatic species that is extremely common throughout the state. It undoubtedly occurs in every county and is probably the most frequently encountered submersed aquatic in Illinois (Map 33).

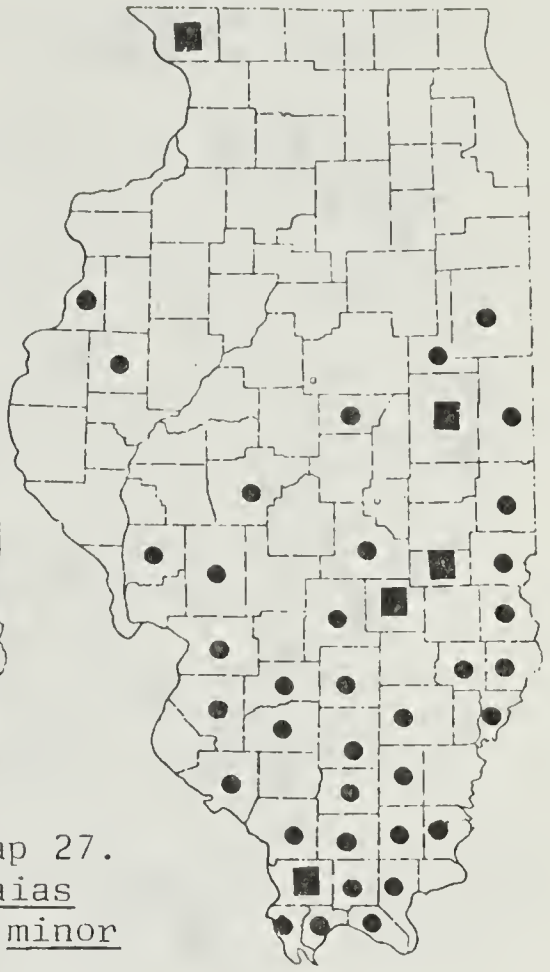
Potamogeton friesii Rupr. A very rare submersed pondweed that has been reported from only the northeast corner of Illinois. The present



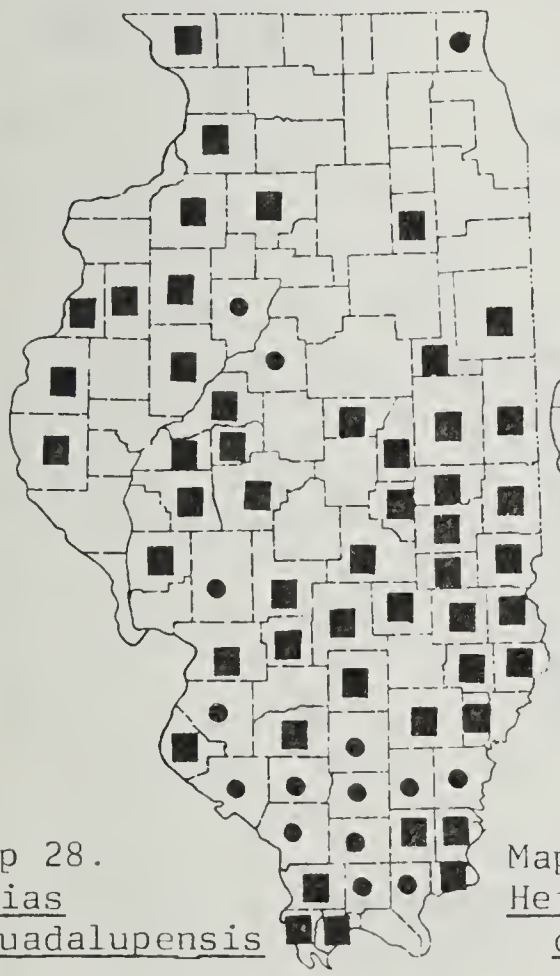
Map 25.
Naias
flexilis



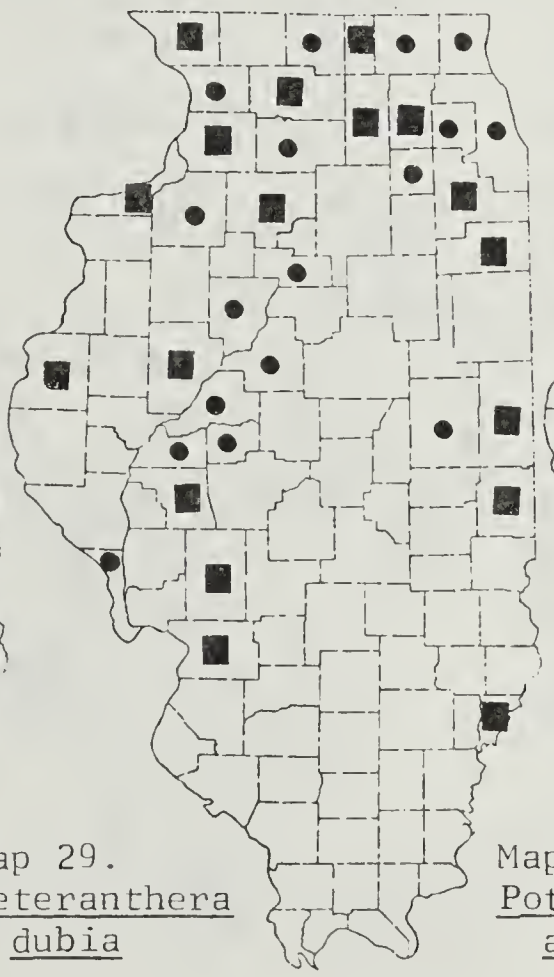
Map 26.
Naias
gracillima



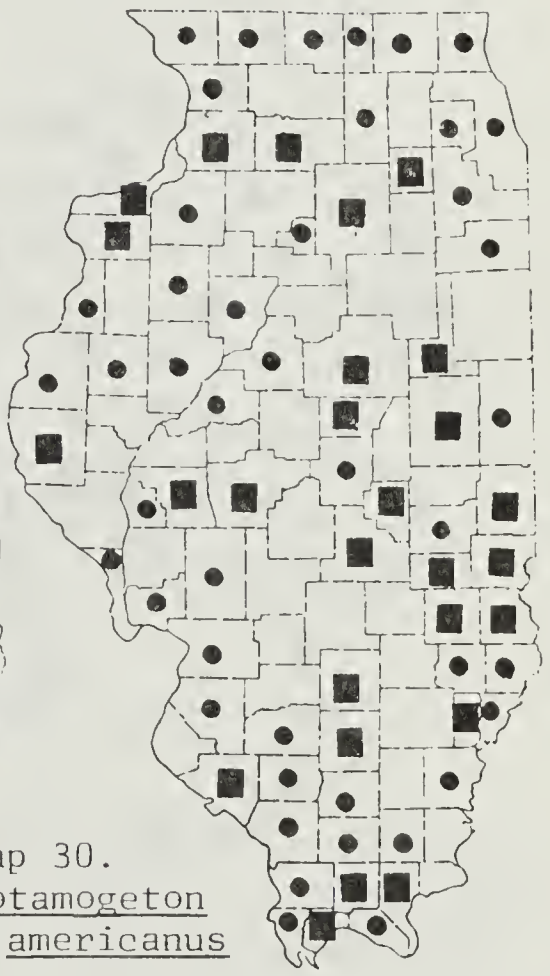
Map 27.
Naias
minor



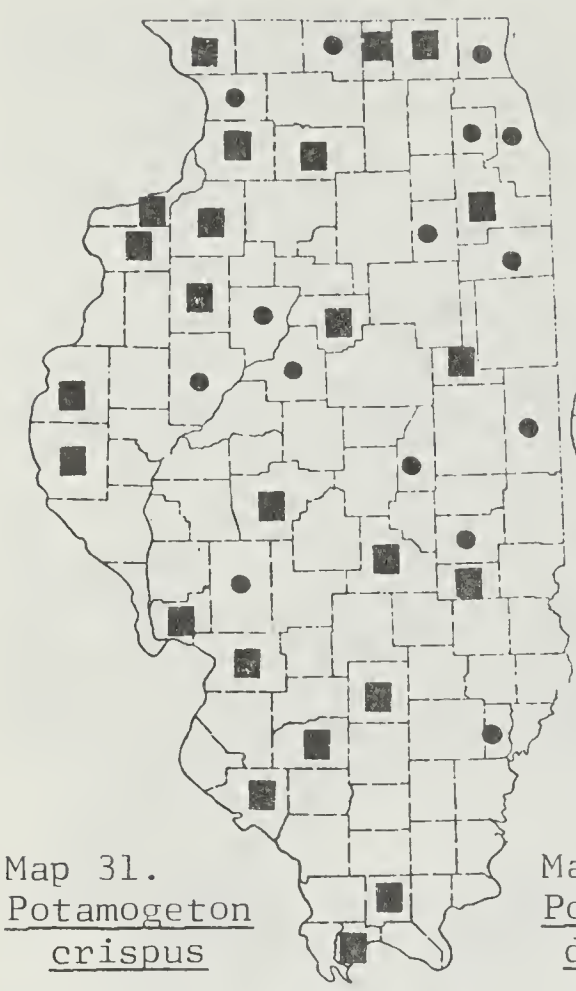
Map 28.
Naias
guadalupensis



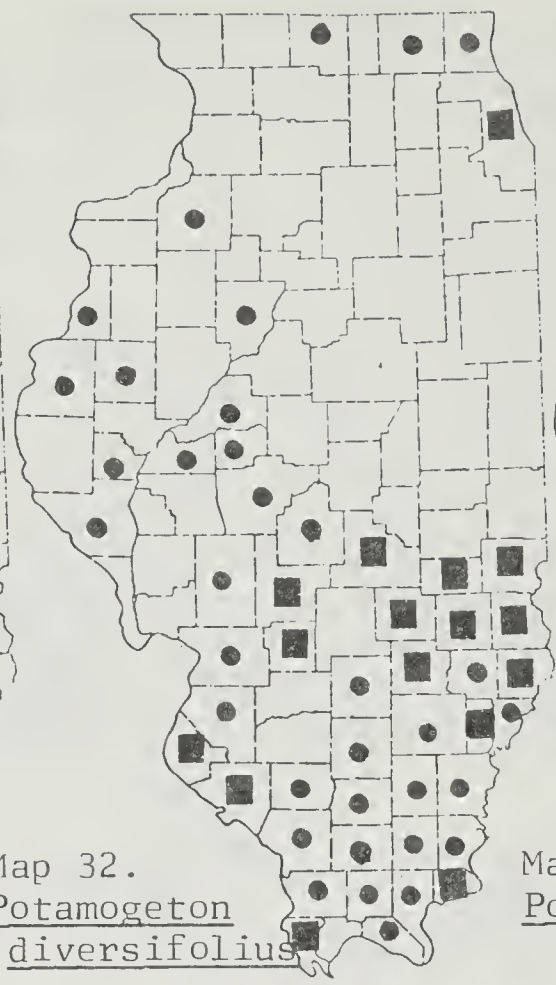
Map 29.
Heteranthera
dubia



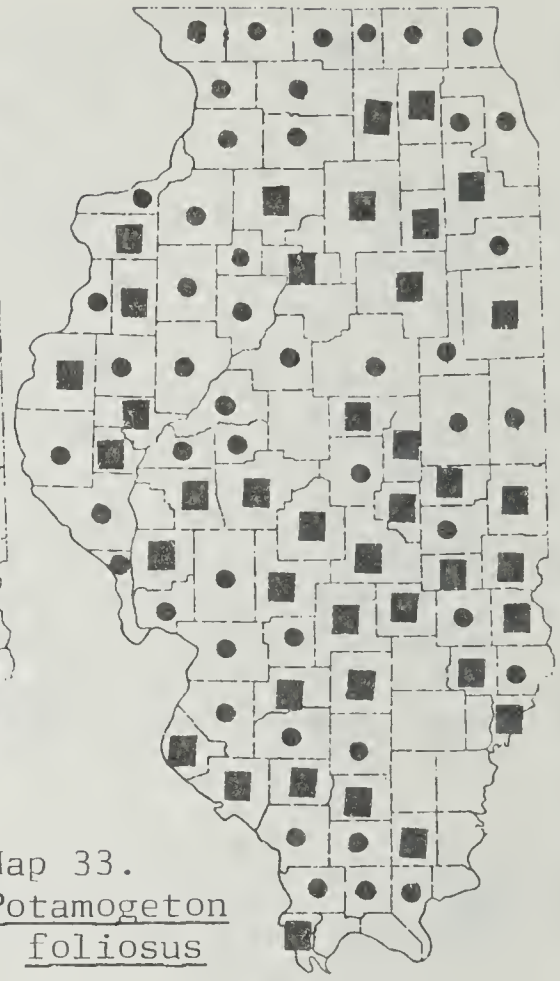
Map 30.
Potamogeton
americanus



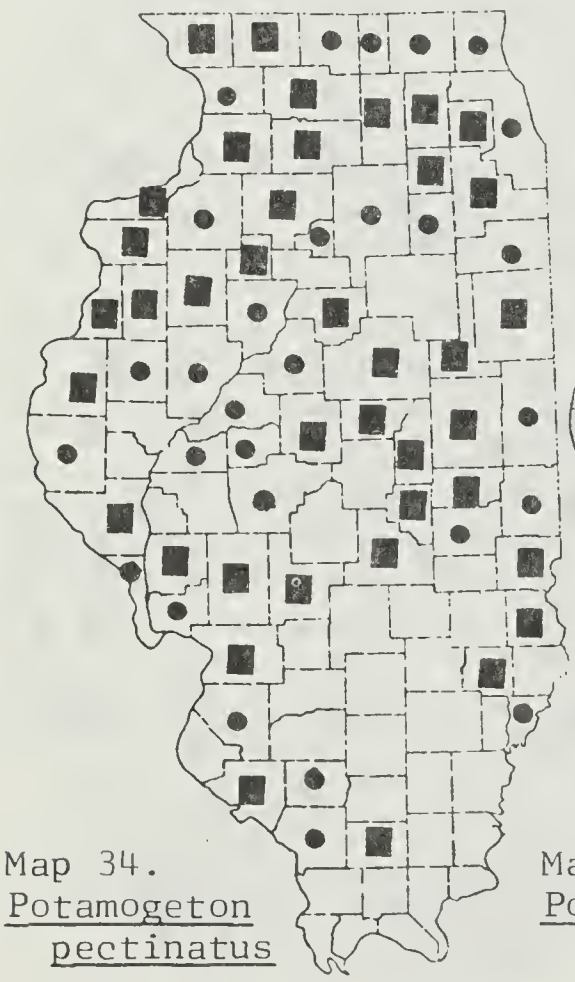
Map 31. Potamogeton crispus



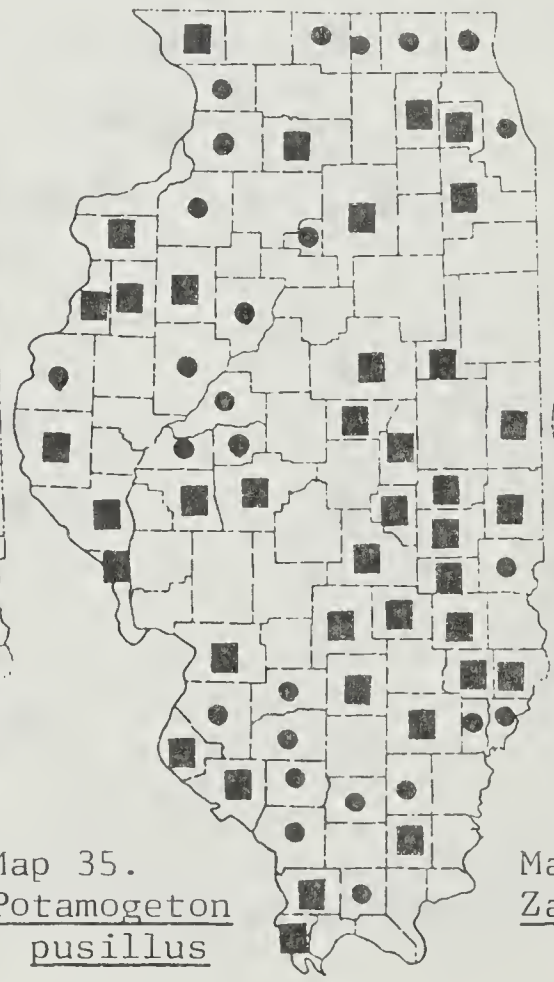
Map 32. Potamogeton diversifolius



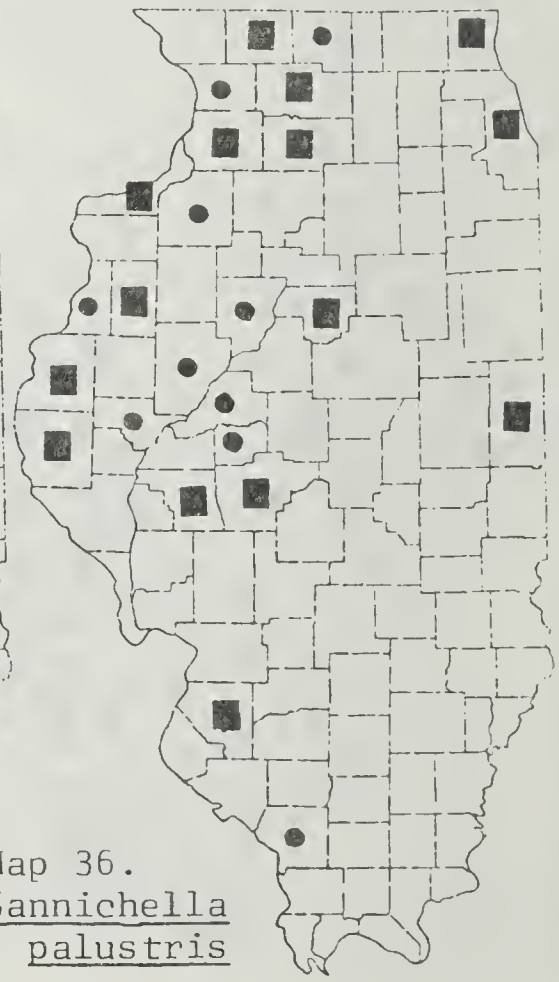
Map 33. Potamogeton foliosus



Map 34. Potamogeton pectinatus



Map 35. Potamogeton pusillus



Map 36. Zannichella palustris

report from Shelby County represents a disjunct and probably temporary range extension as the species was not found when the site was visited the next year.
County records:-- SHELBY: Pond, 5 mi E of Strasburg, Ebinger 10704 (EIU). MCHENRY: Lake at Bear Valley Hunting Club, Dolbeare 1381 (EIU).

Potamogeton illinoensis Morong. This pondweed is occasionally encountered in the northern half of Illinois. It is extremely rare in southern Illinois, being recorded from only three counties.
County records.-- JO DAVIES: Slough, SE of Menominee Station, Evers & Crane 105976 (ILLS). LAWRENCE: Lake at Lawrenceville Sportsman's Club, Lopinot (25 Aug. 1965) (ISM). ST. CLAIR: Lake at Grand Marais St. Park, Neill 4500 (ILLS).

Potamogeton pectinatus L. This submersed pondweed is statewide in distribution. It is fairly common in the northern two-thirds of the state, becoming rare in southern Illinois (Map 34).

Potamogeton pusillus L. This submersed pondweed is fairly commonly encountered throughout the state and probably occurs in every county (Map 35). It is similar to P. foliosus in habit, and fruiting material is necessary for consistent separation.

Potamogeton strictifolius Benn. An extremely rare submersed pondweed that is now known from a second county in the northeast corner of Illinois.
County records.-- LAKE: Grays Lake. Dolbeare 1442 (ISM).

Zannichellia palustris L. A submersed aquatic that is found in scattered localities throughout the state. Most of the specimens seen are from western and northwestern Illinois (Map 36).

ACKNOWLEDGEMENTS

Sincere thanks are expressed to Dr. Floyd A. Swink of the Morton Arboretum for providing additional county records of aquatic plants from the Chicago region.

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POISON-IVY: RELATIONSHIPS WITH THE WEIGHT AND MOISTURE CONTENT OF THE LITTER LAYER

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Abstract

The abundance of Rhus radicans at a bottomland site of the Pine Hills Field Station was determined to be greatest where the dry weight of the accumulations in the litter and fermentation layers is least. A significant correlation exists; however, the relationship between abundance of poison-ivy and average moisture content of the detritus layer was statistically insignificant.

As part of a comprehensive study of the microclimates at the Pine Hills Field Station of Southern Illinois University, data were collected which permit an analysis of the relationship of the dry weight and moisture content of the litter layers with the abundance of poison-ivy (Rhus radicans L.). The specific site was located immediately west of an oxbow lake (Otter Pond) on the Mississippi floodplain (37° 32' 50" N, 89° 25' 55" W). Ashby and Kelting (1964) have described a similar site which they classified as a mature sweetgum community, typical of lowland and major ravine locations.

During the summer months Rhus radicans is the most abundant species in the herbaceous layer at this site, however the distribution and abundance is highly erratic. This pattern is assumed not to be controlled by fire. Observations verified the conclusions of Ashby and Kelting (1964) that this forest has not burned for at least 40 years. Preliminary observations indicated no obvious relationship of poison-ivy distribution with light penetration. Precipitation through-fall to the forest floor also proved inconclusive. Twenty rain gages were randomly placed on the forest floor covering an area of approximately 300 m^2. Through-fall for several rainshowers was observed and some tendency was noted for through-fall to be higher for gages placed by chance in patches of poison-ivy. However, there was much variance and the difference between through-fall for gages in and outside of poison-ivy patches was statistically insignificant. Consequently measures of the litter layer promised improved explanation of poison-ivy distribution and abundance, and an existing experiment was redesigned to include observations of poison-ivy occurrence.

Beginning on 15 May 1970 and ending 8 September 1970, 78 samples of the litter and fermentation layers (A_{oo} and A_{o_2}) were collected using random samplng techniques. A wooden frame, 0.209 m in area, was used as an outline of the area to be sampled. Prescence of poison ivy was recorded when one or more leaflets appeared in the quadrat. All litter except for twigs and branches larger than 0.25 inch (0.64 cm) in diameter was collected down to but not including the mineral soil. Samples were bagged and ovendried at 105°C for 12 hours. The moisture content of each sample was determined in the customary manner to be the ratio of the difference between the wet and dry weight over the dry weight.

The most obvious conclusion which may be drawn from this experiment is that the mean dry weight of the litter layers is consistently less under areas where poison-ivy is located (Table 1). This generalization is true in the early as well as the late summer. And, it is noteworthy that the proportion of samples which recorded occurrence increased during the course of the summer. As expected the standard deviations of the sample weights were large, especially for the nonoccurrence samples where weights in excess of 1600 grams/m^2 were observed. For the entire season's samples the difference between the means of the occurrence and nonoccurrence samples was 216 grams/m^2.

Table 1. The means, standard deviations, and sample size for the dry weight and moisture content of the litter layers. Occurrence and nonoccurrence refer to whether or not Rhus radicans was observed in a sample plot.

	Occurrance			Nonoccurrence		
OVEN DRY WEIGHT (grams/m^2)	M	S.D.	N	M	S.D.	N
Early Summer (May, June)	879.0	136.0	11	1130.7	313.9	17
Late Summer (July-Aug-Sept)	840.8	216.7	28	1019.0	230.2	22
Full-Season	851.6	198.1	39	1067.7	269.7	39
MOISTURE CONTENT						
Full-Season	57%	38.8	39	71%	46.1	39

A corollary of the oven dry weight is the moisture content because one would expect the heavier samples to retain greater amounts of moisture. Table 1 shows that the variance is again large with standard deviations of 38.8 and 46.1 for the respective moisture percentages for occurrence and nonoccurrence. The full-season difference in mean moisture percentage, 57% versus 71% is not significant at 0.05. Consequently the effect of litter moisture is uncertain and substantially masked by litter weight, however a few of the nonoccurrence samples were water-logged. Yet during the driest spells recorded, moisture content of the nonoccurrence samples were consistently lower in moisture than the samples with occurrence. It is probably safe then to conclude that at this site, at the time of experimentation, that litter moisture did not indicate occurrence and certainly did not substantially regulate the abundance of poison-ivy.

In order to examine the degree of relationship of litter weight and moisture with the abundance of poison-ivy, the biserial coefficient of correlation (r_b) was determined and is presented in Table 2. The r_b coefficient is appropriate when either of the correlated variables can be measured on a continuous scale but one variable because of various constraints must be

reduced to two categories (Guilford, 1965). In this case, the abundance of poison-ivy on the forest floor, a continuous variable, was dichotomized into samples which had occurrence and nonoccurrence. Correlations are modest at best; however all correlations between abundance and litter dry weight are significant at 0.05. As a predictor variable litter weight would account for only about 20 percent of the variance in abundance. The coefficient between moisture and abundance (r_b = -0.194) is barely insignificant.

Table 2. Biserial coefficients of correlation (r_b) between litter dry weight and the abundance of Rhus radicans, and, between litter moisture and abundance.

	r_b, weight and abundance	r_b, moisture and abundance
Early Summer	-0.512	---
Late Summer	-0.463	---
Full-Season	-0.455	-0.194*

*not significant at 0.05

Clearly, additional measures of the poison-ivy habitat are required to explain its patterns. However, as the extensive review of Gillis (1971) indicates, very little of a quantitative nature is known about poison-ivy. From the observations presented we see that poison-ivy is less abundant on sites with thick litter and water-logged sites. Poison-ivy tends to favor sites where apparently decomposition rates are higher resulting in a thin litter layer. Consequently there may be a tendency for poison-ivy to invade a larger area during the summer in response to the reduction of litter by decay.

Finally, yet perhaps most significant of the conclusions which may be gleaned from this study is the following. When one of the numerous experiments which require samples of forest litter is designed, it is clear that in spite of the toxic effects of poison-ivy, that all areas should be sampled. To do otherwise would seriously bias many measures of the forest litter system.

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The author wishes to acknowledge Dr. John Parsons, director of the Pine Hills Field Station, for providing logistic support during data collection.

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SPECIES GROWTH CHARACTERISTICS IN A MIXED PINE PLANTATION

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Abstract - A mixed pine plantation of three species can be produced if proper planting and management techniques are used. Nine trees of a species are planted forming an eighteen foot square. Nine such squares will then form a 3 x 3 Latin Square with ample space between species to allow for thinnings and for the development of the slower growing species, resulting in a well developed mixed stand of good quality trees.

INTRODUCTION

Mixed pine stands of good quality trees can be developed by using a mechanical planting pattern and proper cultural practices. Results of a recent study on Sinnissippi Forest in Ogle County, Illinois, show that in a mixed pine plantation of jack pine Pinus banksiana, white pine Pinus strobus, and red pine Pinus resinosa, it is possible to develop good stocking and good quality for all three species. The competition among these three species is not a problem when the plantation is set up in a proper mechanical planting pattern.

A first thinning at 25 years of age was based on tree spacing, tree form, diameter, crown class, and a residual basal area of 90 square feet per acre. Favoring any given species during this thinning was avoided. Growth characteristics and volume tables for each species were analyzed using the statistical package developed by Nie, Bent, and Hull (1).

HISTORY

The one-acre study area located on Sinnissippi Forest in Northern Illinois was planted in 1948 with a spacing of 6 feet by 6 feet. The planting pattern illustrated in Figure 1 was designed with each square containing nine trees of a common species. Each nine squares (81 trees) is in the form of a 3 x 3 Latin square repeated throughout the acre.

In 1957 and 1964, 10 and 17 growing seasons after planting, mean diameter and mean height were calculated. The basal area per acre in 1964 for the combined stand was 108 square feet with basal area for jack pine being considerably higher than for either red or white pine (see Table 1).

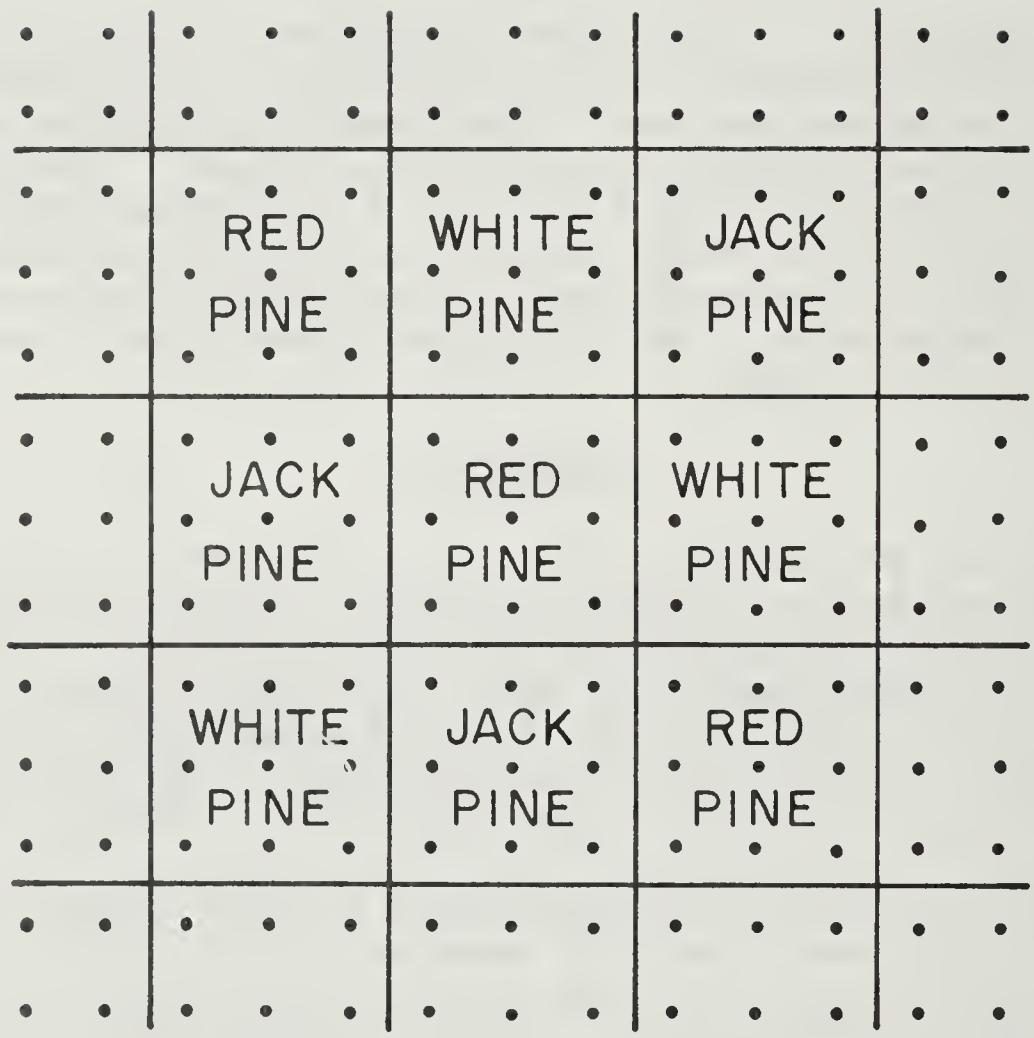

FIGURE 1. CHECKERBOARD ARRANGEMENT OF PLANTATION

The one-acre plantation is on Sparta(2) loamy sand, a deep sand soil that is excessively well drained. A very small corner in the plantation is Jasper(2) soil type which is dark well drained soil with a brownish clay loam subsoil containing sandy loam at depths below 4 feet.

A 0.476 acre study plot consisting of 64 nine tree blocks was established in the center of the 1-acre plantation. In 1973, 25 growing seasons after planting, the study plot was thinned to 90 square feet of basal area per acre. The combined variable formula which expresses tree volume as a linear relationship of D^2H[2/] was used for volume computation as described by Spurr (3): $Y = a + bX$; where, Y is equal to volume, "a" is the Y intercept, "b" is the slope coefficient, and X represents $(DIB)^2(H)$[3/]. To determine the regression constants, "a" and "b", 10 trees of white pine, 10 of jack pine and 12 of red pine were drawn at random by diameter classes from the trees marked for thinning. Trees which appeared to have abnormal form were rejected. The measurements to determine volume were taken from the 32 sample trees and a regression equation was thus developed for each species.

Table 1. Development of the 25-year-old stand

	1957			1964				1973	
	DBH	Ht	SURVIVAL	DBH	Ht	BASAL AREA	SURVIVAL	BASAL AREA BEFORE THINNING	SURVIVAL
White pine	1.9"	13'	89%	3.7"	25'	25	77%	46	68%
Red pine	2.7"	14'	95%	4.3"	26'	38	95%	63	92%
Jack pine	3.4"	17'	94%	4.7"	31'	45	94%	64	91%
						108		173	

In addition to the sample trees, DBH, DIB, and heights were taken from all remaining normal trees marked for thinning. These measurements were then used in the regression equation to establish the volume tables by species.

RESULTS

Table 2 shows the principal study plot characteristics before and after thinning. Early measurements in the plantation as seen in Table 1 bear out the height and diameter relationships commonly noted among these three species. One can see from Table 2 that these same relationships in height and diameter are still evident among the trees marked for thinning. Jack pine, however, has not been able to maintain the advantage in height and diameter growth as indicated in earlier measurements.

The residual trees appear to show fairly consistent stocking, diameter, and basal area relationships after the commercial thinning.

Volume in red pine is appreciably higher due to the higher stocking and the longer mean merchantable length. The number of trees per acre remaining in

---

2/ D^2H represents diameter square times height.

3/ $(DIB)^2(H)$ represents diameter inside bark squared timed height.

Table 2. Study plot stand characteristics before and after thinning.

Species	Before thinning				Cut				Residual			
	WP	RP	JP	ALL	WP	RP	JP	ALL	WP	RP	JP	ALL
Mean DBH	5.4	5.6	5.6	5.6	4.5	5.0	5.5	5.1	6.3	6.1	5.8	6.1
Mean DIB	--	--	--	--	4.3	4.7	5.1	4.7	--	--	--	--
Basal area/acre	45.64	63.13	63.63	172.4	14.88	28.83	38.68	82.4	30.76	34.30	24.95	90.0
Mean Merchantable Ht.[1/]	--	--	--	--	21.0	30.7	30.7	27.6	--	--	--	--
Mean Nonmerchantable Ht.[1/]	--	--	--	--	15.6	11.5	13.2	13.3	--	--	--	--
Mean total height	--	--	--	--	38.2	41.4	45.2	41.8	--	--	--	--
Mean cu.ft. volume	2.87	3.51	3.47	3.32	1.95	2.85	3.31	2.82	3.77	4.30	3.75	3.96
Number of trees/acre	269	363	361	993[2/]	133	197	225	555	136	166	136	438
Total cu.ft. volume[3/]	772.0	1274.1	1252.7	3296.8	259.3	561.5	743.6	1565.1	512.7	713.8	510.0	1734.5

[1/] Sample trees only; 2" minimum top diameter of last stick for merchantable length.
[2/] 1210/acre minus 217 (mortality).
[3/] Discrepancies due to rounding off.

the stand after thinning was 136, 166, and 136 for white, red, and jack pine, respectively.

After plotting the regression equations and fitting the regression lines, a volume table by diameter classes was developed for each species which was used to determine volumes for the residual stand (see Table 3). Data below the line was projected from the regression line.

Table 3. Cubic feet volume inside bark by species and diameter

DBH	SPECIES White Pine	Red Pine	Jack Pine
4	1.3	1.4	1.2
5	2.4	2.8	2.6
6	3.4	4.2	3.9
7	4.5	5.5	5.3
8	5.6	6.8	6.6
9	6.6	8.2	8.0

STATISTICAL ANALYSIS

The sample data collected yielded the statistical coefficients and regression constants shown in Table 4.

The correlation coefficients for all species approach 1.0, indicating that there is a very good linear relationship between Y and X.

Table 4. Results of the statistical analysis based on 32 sample trees

Species	No. of trees	Mean and std. error of estimate X DBH	Y HT	Y Vol.	Regression constants X on Y a	b	Correlation coefficient X on Y
White pine	10	4.49 (.425)*	37.15 (2.029)	1.95 (.418)	.04999	.00262 (.00009)*	.99572
Red pine	12	5.52 (.457)	42.60 (1.175)	3.64 (.636)	.01618	.00293 (.00012)	.99107
Jack pine	10	5.61 (.299)	44.43 (.600)	3.47 (.405)	.09300	.00284 (.00022)	.97774

* Std. error

Table 5 shows the student's "t" test results at the .05 level of significance. This test is based upon the 32 sample trees. Tests of significance were run as described by Steel and Torrie (4) and Huntsberger (5).

Table 6 shows results after adding a larger number of height and diameter measurements to the sample trees and using the regression equations to obtain volumes. The student's "t" test was used to determine significance between volume means.

It was hypothesized that there is a significant difference in height, DBH, and volume between species thus precluding the possibility of alternate species planting.

DISCUSSION

The commercial thinning left a residual stand of 90 square feet of basal area per acre, and improved the competitive relationship for white pine. By comparing the mean heights in the "cut" column of Table 2, it appears that the red pine and jack pine would eventually suppress and kill the white pine that are growing immediately adjacent to these species, the average height being considerably less in the white pine. In later years, the jack pine may gradually be eliminated as evidence in the "residual" column indicates. An examination of the residual mean diameters of the three species, suggests that the white pine and red pine mean heights are approaching if not exceeding the mean height of jack pine.

Comparing the residual stand stocking with the stocking before thinning, the residual stand represents 51% of the white pine, 46% of the red pine, and 38% of the jack pine. The high percentage of residual white pine can be traced to the lower stocking before thinning. The stocking before thinning for red and jack pine are consistent, but the residual stocking of jack pine is less than that for red pine. There is a strong indication that the jack pine represents the poorest quality trees. However, as a result of the mechanical planting pattern, a sufficient stocking of quality jack pine was achieved. In fact, this stocking is identical with the white pine. Red pine apparently is the species which is most consistent in growth characteristic qualities.

The volume comparisons between species show white pine to have consistently lower volumes by DBH classes than either red or jack pine (see Table 3). Red pine has the highest volumes by DBH classes. As diameter increases, the range of volume between white pine and jack pine increases. It also increases between white pine and red pine but at a slower rate. As diameter increases, the range of volume decreases between red pine and jack pine. The characteristics in these volume ranges between species can be traced to different form factors for the three species.

It appears that red pine will produce the maximum wood volume for this site. A managed mixed pine plantation on a similar site with the same species will surely sacrifice maximum wood volume.

Table 5. Comparison of height, DBH, and volume differences among species using 32 sample tree

Species comparison	Total height	DBH	Volume
White pine and red pine	Significant[1/]	Not significant	Not significant
Red pine and jack pine	Not significant	Not significant	Significant
Jack pine and white pine	Significant	Not significant	Significant

[1/] Significant at the 0.05 level of confidence using students "t" test.

Table 6. Volume statistics and significance at .05 level

Species	Number of trees	Mean Volume and std. error of estimate	Volume comparison	.05
White pine	33	1.95 (.187)*	White pine and red pine	Significant
Red pine	60	2.85 (.177)	Red pine and jack pine	Significant
Jack pine	57	3.31 (.131)	Jack pine and white pine	Significant

*Std. error.

CONCLUSION

The residual stocking, diameter, basal area and volume (Table 2) show a much more consistent picture when compared with the cut trees. With 48% of the total basal area removed and 56% of the trees cut during the thinning, all residual trees should respond well until another thinning is necessary in 8 to 10 years.

The next commercial thinning which could produce small sawlogs may necessitate a heavier cut in red pine to maintain a balanced stocking between the three species; otherwise the jack pine stocking would probably be reduced by competition from the red pines. The residual diameter and basal area of jack pine suggest that at the present age of the tree, it may not continue to compete with the other species as in the past.

At this point of plantation development with the usual silvicultural practices performed, the data suggests that a mixed pine plantation of the three species studied can be easily managed to maturity.

The good residual stocking among species appears to be a direct result of the nine tree Latin square blocks established when the plantation was designed.

The question arises as to the possibility of achieving satisfactory results by using a mechanical thinning, such as cutting every other row. It is conceivable that this method would give good results, but this kind of thinning should be done before the plantation is 25 years old. Examination of the tables suggest that at this age too many white pine of inferior quality might be left for the residual stand. This is further evident in view of the higher mortality rate of white pine after 25 years of age. Basal area figures indicate that the plantation could justifiably have been thinned at about 15 years of age. A mechanical thinning at that time could very well have left the plantation with sufficient stocking of all species. The second thinning would unquestionably require the selection method to eliminate the undesirables carried over from the mechanical thinning.

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TWO EARLY PENNSYLVANIAN FLORAS OF WESTERN ILLINOIS

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ABSTRACT

Two sites in western Illinois have yielded a large number of well-preserved early Pennsylvanian plant fossils and provide information concerning the environment. The fossils from Brown County represent an upland flora; those of Rock Island County are a mixture of upland and swamp plants. Both floras contain *Megalopteris, Lesleya,* and *Lacoea.* The high percentages of Pteridospermales and Noeggerathiales and the lower percentage of ferns and lycopsids in these floras contrast with the composition of the lowland or swamp floras.

LOCATIONS

In recent years two sites in western Illinois have yielded a large number of well-preserved plant fossils. The first is located in Brown County, on the La Moine River about 12 km north - northeast of Mt. Sterling (Fig. 1). The second locality is in the Allied Stone Company quarry on Vandruff Island, Milan, Rock Island County. Both exposures are located on the western margin of the Illinois Basin and the eastern flank of the Mississippi River Arch and near the western edge of the existing Pennsylvanian strata.

Major valleys are known to have drained east and southeastward across the pre-Pennsylvanian surface into the Illinois Basin (Smith, 1941; Horberg, 1950). Valleys up to 140 m deep and up to 32 km wide are known from other parts of the Illinois Basin (Bristol and Howard, 1971).

The deposits described below fill tributaries of major valleys. The exposure in Brown County reveals a ravine eroded into St. Louis - Salem (Mississippian) limestone and dolomite and filled with mud, silt and sand during early Pennsylvanian time. The ravine was steep-sided and at least 12 m deep (Fig. 2).

The deposits in Rock Island County occur in channels which were basically east-west with sharp "dog-legs," possibly controlled by joints in the limestone. The channels are about 4 m deep, 8 m wide, steep-sided, flat-bottomed (Fig. 3) and are filled with mud and quartz sand. They were eroded in an otherwise flat surface developed on Cedar Valley (Devonian) limestone.

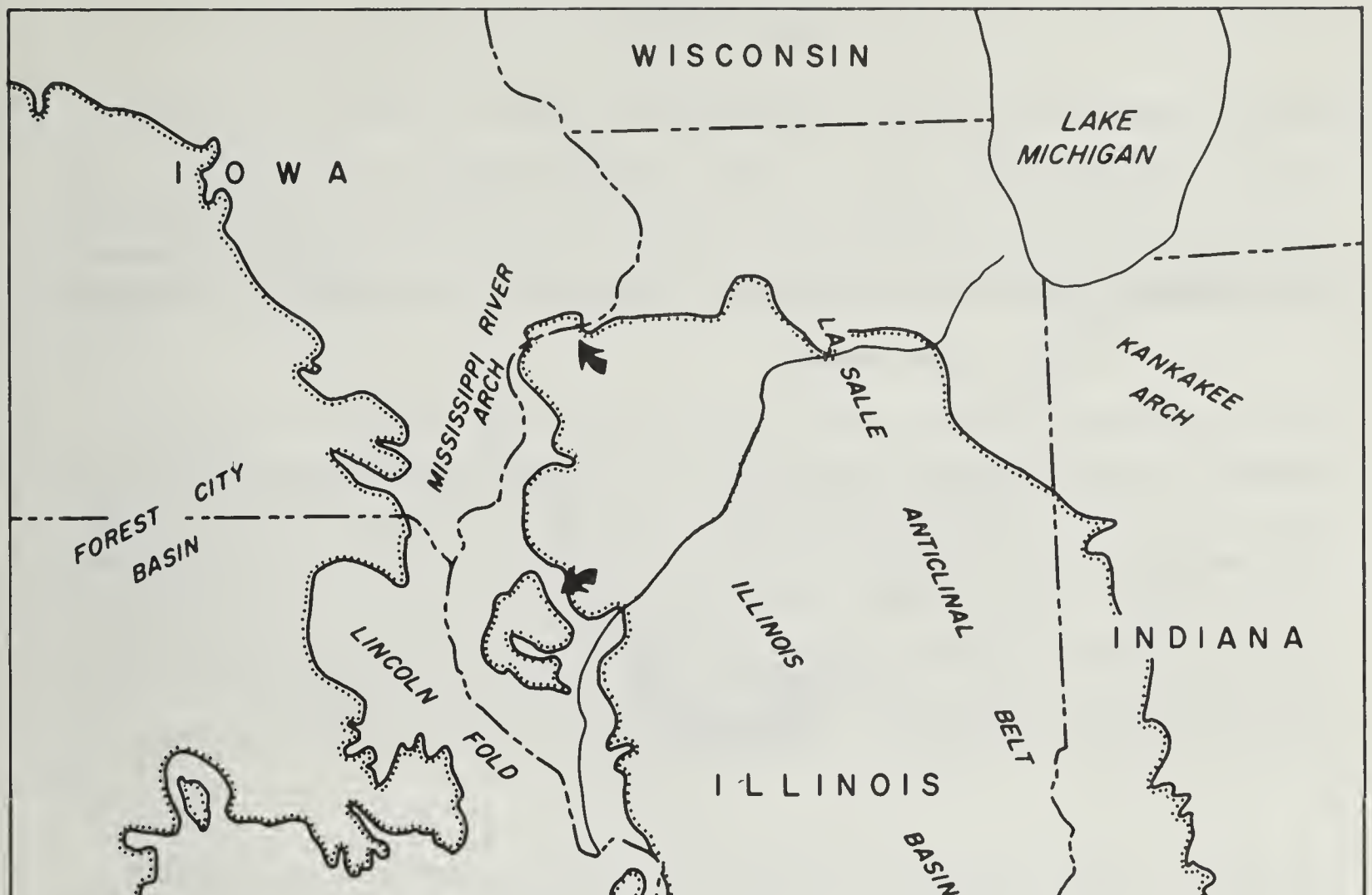


Figure 1. Map showing locations in relation to major structural features. Base map courtesy Illinois State Geological Survey.

The fossils from these two localities represent plants which grew on the uplands between the major valleys. This environment was obviously better drained and probably drier than the swamp which existed in the deeper basin to the southeast.

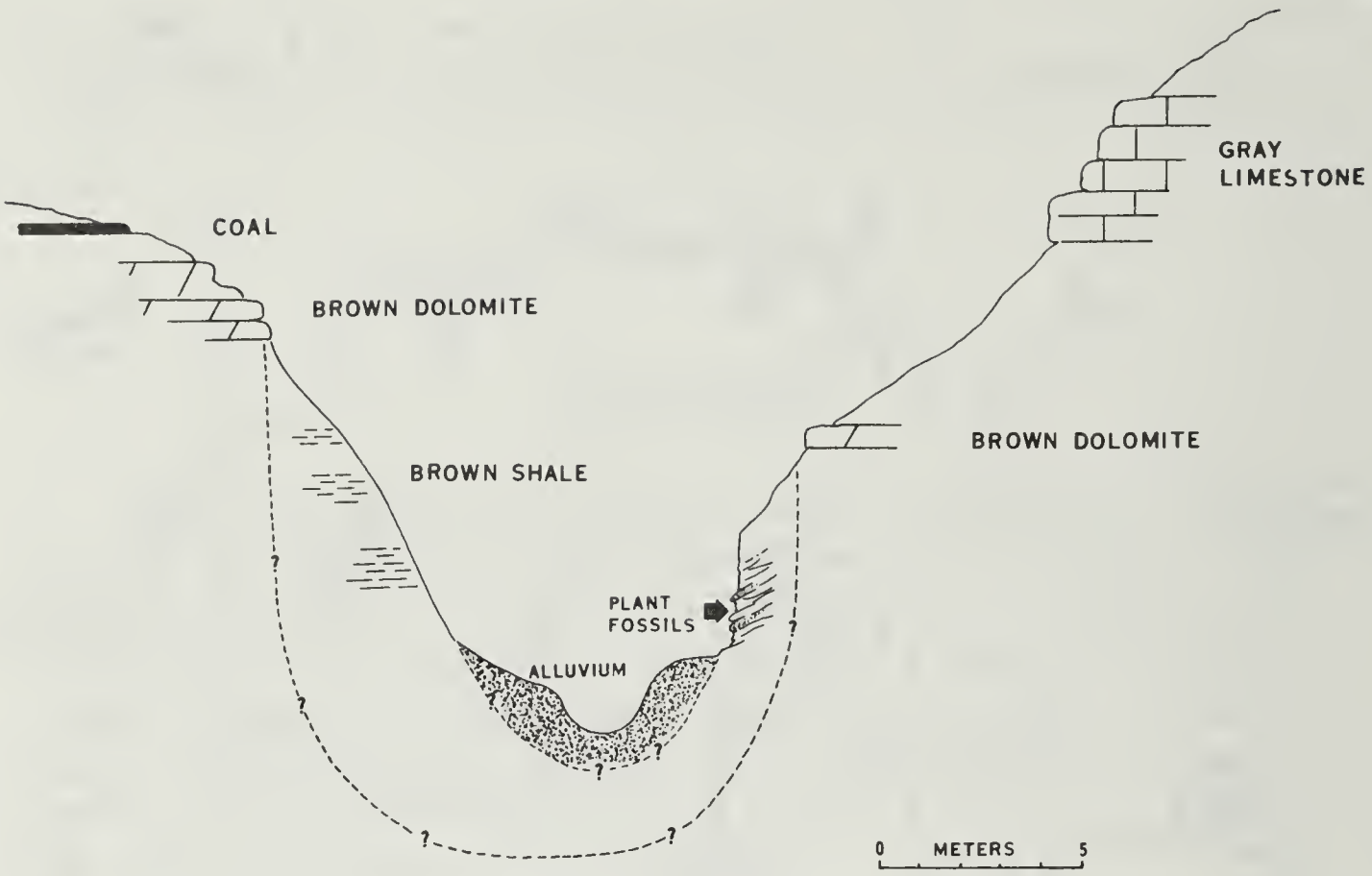


Figure 2. Cross section of the Brown County locality.

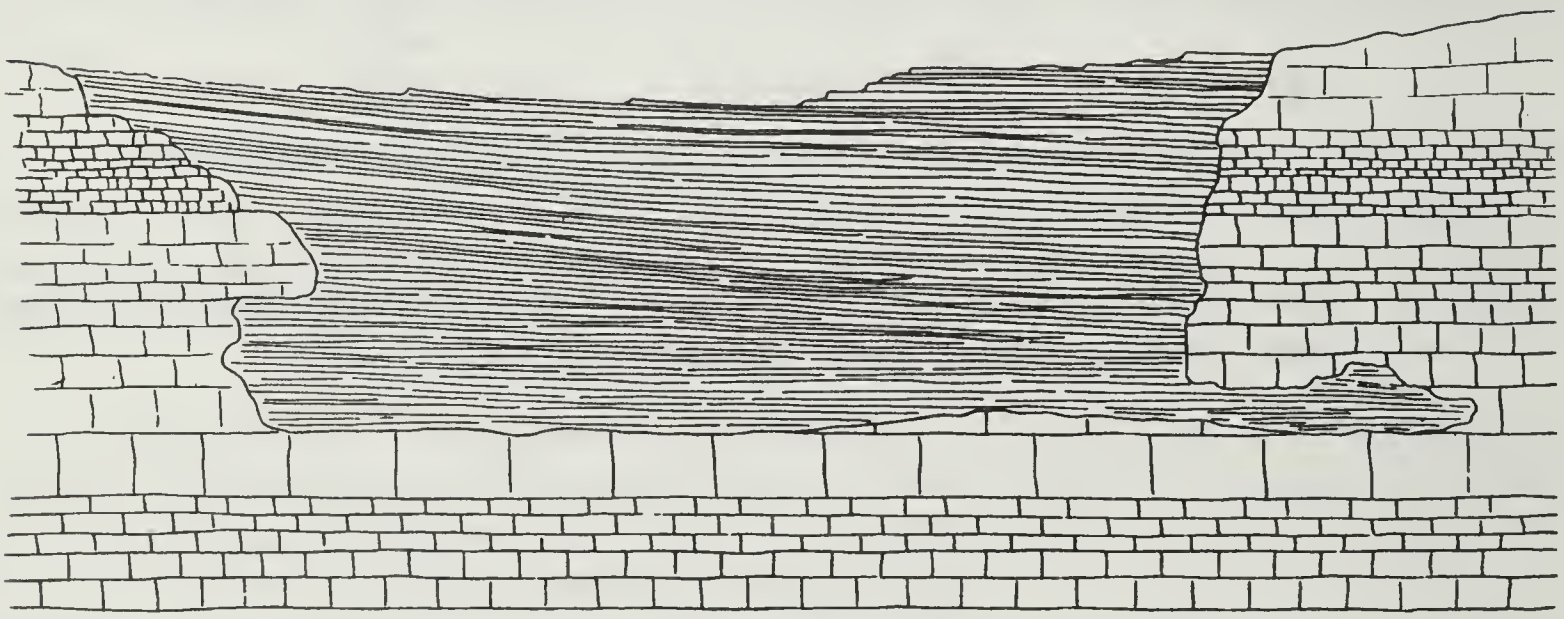


Figure 3. Cross section of a channel at the Rock Island site.

THE FLORAS

Twenty-five genera of foliage, fructifications and stems have been identified from the Allied Stone Company quarry (Table 1). The most abundant taxa are *Megalopteris, Cordaites, Lesleya, Samaropsis,* and *Cordaicarpus.* At the Brown County site twenty-one genera have been identified. Among the most common are *Lacoea, Sphenopteris, Cordaites,* and *Alethopteris. Megalopteris* and *Lesleya* are well represented.

As shown in Table 1, the two floras have many genera in common; the main differences are in the relative abundance of certain genera and the presence or absence of certain others. Lycopods are common in the Rock Island flora but very rare in the Brown County flora; only one determinable specimen and two fragmentary specimens of *Lepidodendron* have been found there; *Lepidophloios* is absent in both localities. Lycopods are the dominant plants in most lower and middle Pennsylvanian floras of the basin. Sphenopsids and *Cordaites* are more abundant in parts of the Rock Island flora than in the Brown County flora; ferns are more common in the Brown County flora.

Because several genera are unusual a few general statements follow. These and other taxa will be described in detailed reports on each locality (Leary and Pfefferkorn, in press; Leary, in preparation).

Megalopteris fronds are simple pinnate and near the tip appear pedate. The largest fronds, those of *M. dawsoni,* apparently consist of only three pedate lobes (Plate 1, Fig. 1); those of *M. ovata* bear numerous pinnules. The pinnules are generally large, straplike or lanceolate with a decurrent base. The midvein is thick with longitudinal striations often present; the lateral veins are dense and divide one to three times.

Lesleya foliage is similar to *Megalopteris* pinnules but consists of simple leaves (Plate 1, Fig. 2). These leaves are large, greater than 30 cm long and 10 cm wide. The midvein is broad, though not as broad as that of *Megalopteris;* the lateral veins are curved and divide once or twice. *Lesleya* and *Megalopteris* are also separated on the basis of epidermal structures (Florin, 1933). David White (1931, p. 275, 276) noted that *Megalopteris* and *Lesleya* are unique to uplands developed on carbonates.

Mesocalamites is distinguished from *Calamites* and *Archaeocalamites* on the basis of the continuity of ribs across the nodes. *Calamites* ribs alternate whereas some of the *Mesocalamites* ribs alternate and some are continuous. On the other hand *Archaeocalamites,* an older form, has all ribs continuous across the nodes.

Lacoea (Plate 2, Fig. 1) is a cone consisting of semicircular sporophylls which alternate on a thick axis. Although Read (1946) considered *Lacoea* a probable pteridosperm, specimens from Brown County, Illinois, permitted a reinterpretation and it is now considered a Noeggerathialian (Leary, 1973).

TABLE 1. Genera present at the localities in Brown and Rock Island counties, Illinois.

	Brown County	Rock Island County
Lycophytina		
Lepidodendron	vr	c
Lepidophylloides		c
Lepidostrobus		c
Stigmaria		vr
Sphenophytina		
Mesocalamites	c	c
Asterophyllites	c	c
Annularia	vr	
Calamostachys	c	c
Sphenophyllum		r
Filicophytina (Ferns)		
Alloiopteris	c	vr
Dactylotheca	r	
Pteriodospermales		
Alethopteris	c	r
Sphenopteris	a	c
Lagenospermum	vr	
Telangium	c	r
Megalopteris	c	a
Lesleya	c	a
Samaropsis	c	a
Neuropteris?		vr
Mariopteris?	vr	vr
Whittleseya/Aulacotheca		vr
Rhodea	r	vr
Noeggerathiales		
Lacoea	a	c
Palaeopteridium	c	?
Gulpenia	r	vr
Cordaitales		
Cordaites	c	a
Cordaicarpus	r	c
Cordaianthus		r
Artisia		vr

Approximate abundance indicated by the following: vr - very rare (1, 2), r - rare (3 - 5), c - common (5 - 25), a - abundant (> 25). Based upon 350 specimens from each locality.

Gulpenia is characterized by small deeply lacerated pinnules attached spirally to a thin axis. In compression *Gulpenia* bears a superficial similarity to *Sphenophyllum* but the pinnules clearly alternate (Plate 2, Fig. 6,7).

Palaeopteridium has been often found associated with *Lacoea* (=*Discinites,* Nemjc, 1937) and perhaps the two belong to the same plant. The overall form of the *Palaeopteridium* pinnule is wedge-shaped, spatulate or diamond-shaped (Plate 2, Fig. 5). The pinnules have a stalklike base which is often not visible, giving the appearance that the pinnule is attached by a rather large part of the base. The upper margin bears numerous sharp-pointed teeth.

Although the differences in generic composition of the two floras might be in part due to a slight age difference (see section following), they are more likely to reflect slight environmental differences.

Several studies have been made of paleoecological differences in Pennsylvanian floras and several environments have been recognized (see Peppers and Pfefferkorn, 1970, p. 68, 69 for summary). Although the Colchester (No. 2) Coal member (Westphalian D) is considerably younger than the floras described here, more data is available for that period of time and the generalizations of major plant predominance are probably valid for earlier floras, with the exception of the tree ferns which were very rare or absent in the lower Pennsylvanian. The dominant groups for each environment are indicated below, but it must be kept in mind that all other groups were also present.

Swamp - lycopods or sphenopsids

Levees and floodplain - pteridosperms, ferns, sphenopsids

Upland - pteridosperms, *Cordaites,* Noeggerathiales (rare)

The flora preserved in the Allied quarry in Rock Island County combines features of several floras. The concentration of some genera, in particular the lycopods and sphenopsids, in certain areas and horizons indicates possible changes in climate and microenvironment. The sediments in the channels preserved at Rock Island show no signs of drying. Apparently the presence of a permanent body of water permitted the growth nearby of normally lowland or swamp plants on an otherwise dry upland.

The plants growing on the bluffs and well-drained uplands of northern Brown County were subject to more arid conditions. Thus the flora preserved at this site consists almost exclusively of genera characteristic of the uplands. The paucity of lycopods and ferns in the Brown County flora is in sharp contrast to their abundance in the swamp floras.

THE AGE OF THE FLORAS

Based upon stratigraphic evidence alone, the age of the Brown County flora can be determined only as post-Meramecian (post lower Visean) -- pre-Lampasas (pre-Westphalian B). On the basis of limited spore analysis the age is Morrowan (Namurian B-Westphalian A) (R. Peppers, personal communication). The age determination based upon the macrofossils agrees with this conclusion although the previously recognized ranges of some species could indicate ages both older and younger. The age is probably Namurian B (Leary and Pfefferkorn, in press).

The age of the Rock Island County flora is even less well established. The stratigraphic evidence places the age as post-Devonian -- pre-Pleistocene or perhaps pre-DesMoinesian (Westphalian C) (Edmund and Anderson, 1967, p. 13). Both spore and plant macrofossil studies are incomplete but at least one species (*Sphenophyllum tenerrimum,* Plate 2, Fig. 8) indicates a late Mississippian (Namurian A) age for the flora. Because of the strong environmental/facies control of the flora composition, age determinations based solely on a few plant species are approximate.

SUMMARY

Although the sites in Rock Island and Brown counties will continue to be studied and other sites sought, several conclusions can already be drawn:

1) The exposures in Rock Island and Brown counties provide glimpses of the landscape which existed on the western margin of the Illinois Basin at the beginning of Pennsylvanian sedimentation. These localities, in addition to drilling records, indicate the presence of steep-sided channels and valleys separated by relatively flat uplands.

2) The plant fossils preserved in sediments filling channels, valleys and sink holes illustrate the early Pennsylvanian upland floras. These floras were dominated by *Megalopteris, Lesleya,* and *Cordaites.*

3) By examining these upland floras we can better realize the diversity of plant life during the early Pennsylvanian. The composition of the upland floras differs from that of the lowland and swamp floras in the high proportion of Pteridospermales, *Cordaites* and Noeggerathiales and the low percentages of lycopsids and ferns.

4) Several fossil plant species found in these localities indicate that Pennsylvanian sedimentation in western Illinois began earlier than previously known. The Brown County deposit is Namurian B (lower Morrowan) and the Rock Island County sediments are perhaps as old as Namurian A (normally considered uppermost Mississippian).

ACKNOWLEDGMENTS

The author wishes to acknowledge the cooperation and assistance of Jerry Morris, Supervisor of the Allied Stone Co. quarry in Milan, Illinois, and the Mark Spencer family of Brown County. Without their active assistance, neither of these localities would have been studied. The comments and suggestions of Dr. Tom L. Phillips, University of Illinois, and Dr. Herman W. Pfefferkorn, University of Pennsylvania, are also greatly appreciated.

DESCRIPTION OF PLATES

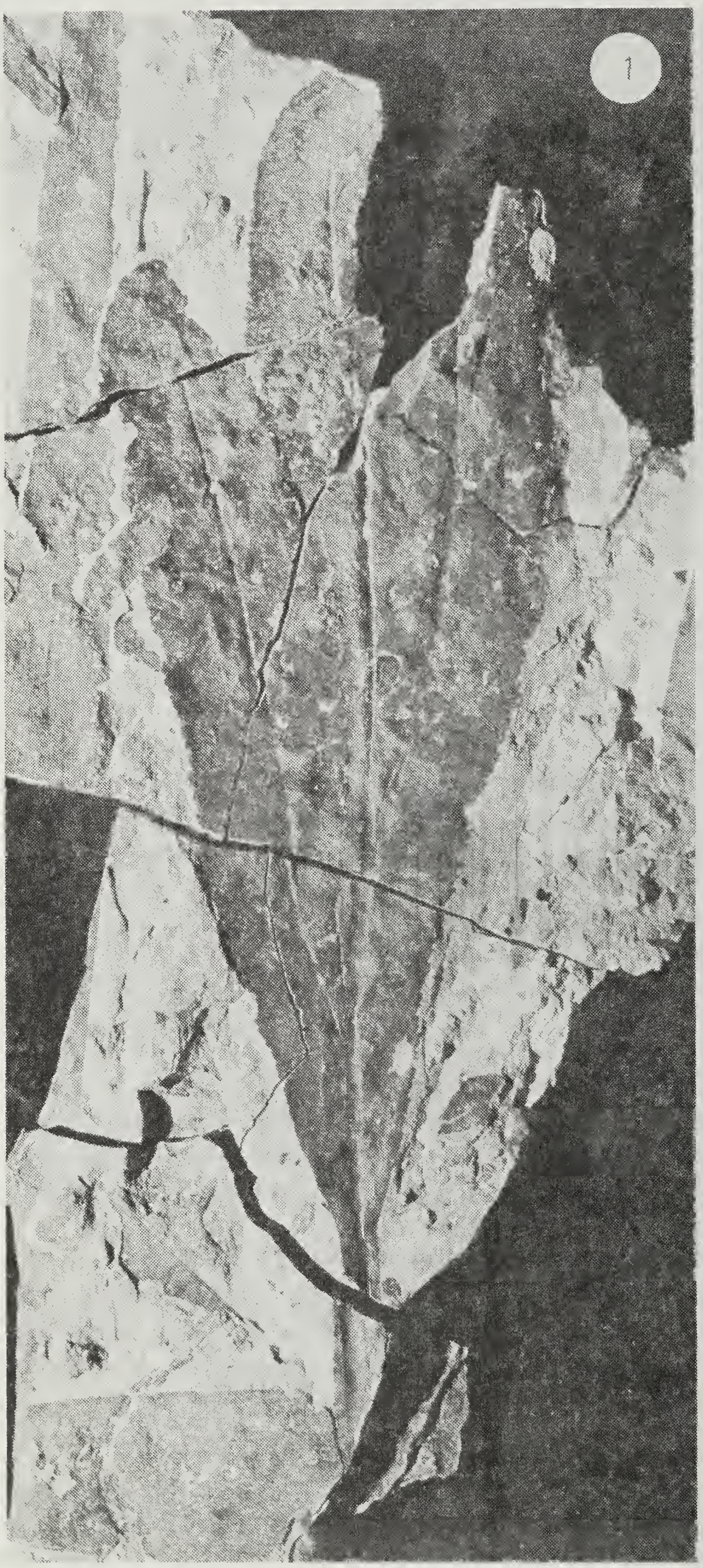
Plate 1

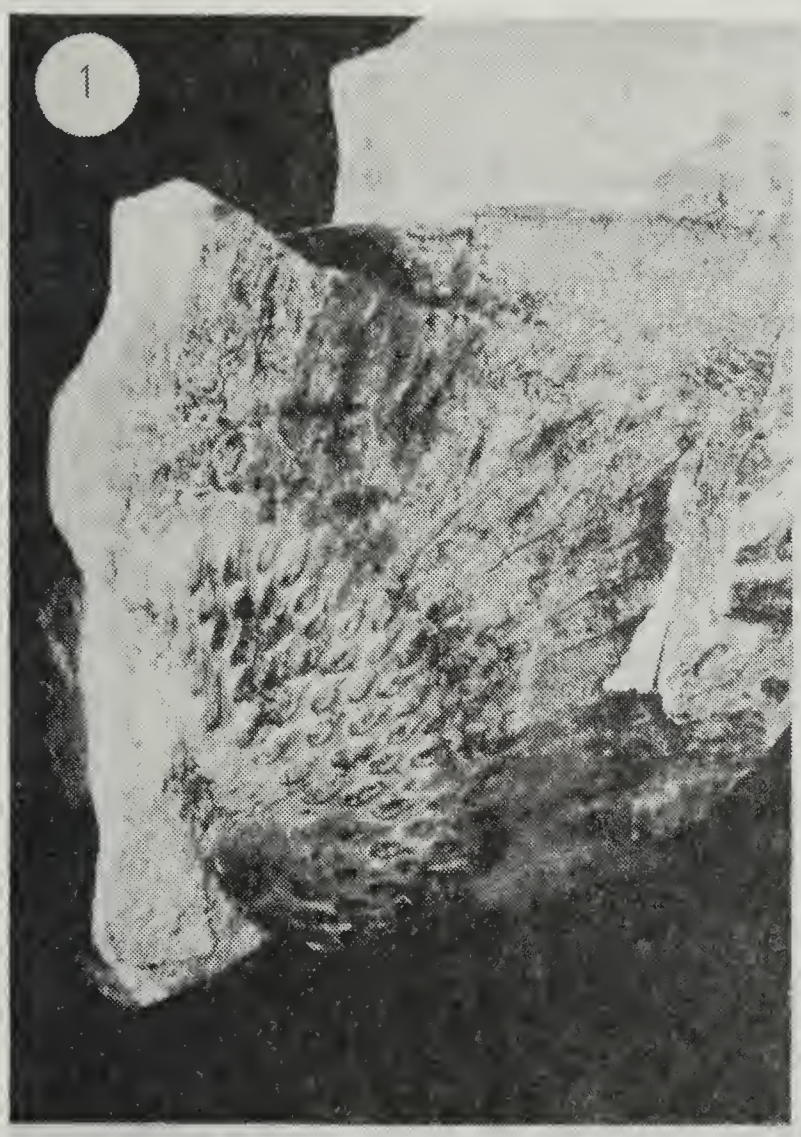
Fig. 1 - *Megalopteris dawsoni* X½
Fig. 2 - *Lesleya sp.* X½

Plate 2

Fig. 1, 2 - *Lacoea seriata* X1
Fig. 3, 4 - *Samaropsis newberryi* X1
Fig. 5 - *Palaeopteridium reussi* X2
Fig. 6, 7 - *Gulpenia limburgensis* X2
Fig. 8 - *Sphenophyllum tenerrimum* X1

PLATE 1

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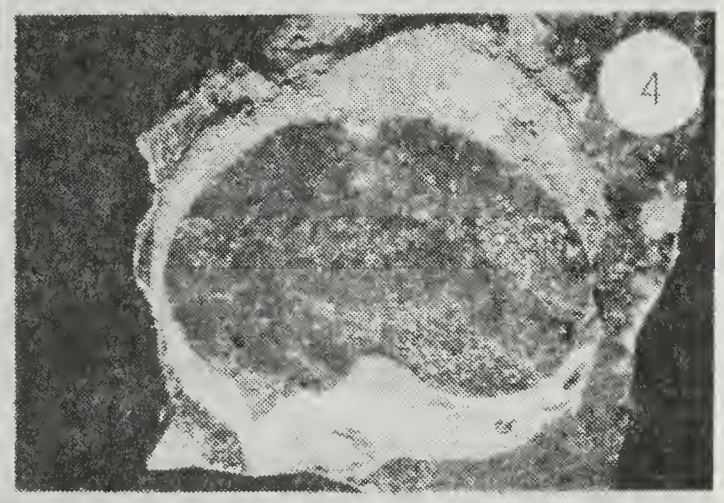
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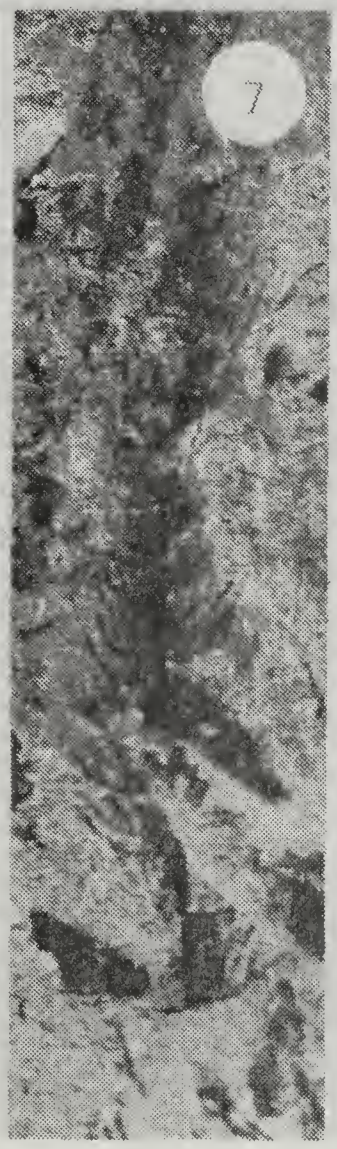
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TRANSACTIONS, ILL. STATE ACAD. SCI.
Vol. 67, No. 4 (1974)

A STATE RECORD FOR CHIMAPHILA MACULATA (L.) PURSH. IN ILLINOIS

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In the spring of 1974, a new species of vascular plant was recorded for Illinois. One individual of spotted wintergreen (Chimaphila maculata (L.) Pursh.) was found in the Lusk Creek watershed (Pope County) on a moderately dry, south-facing, site. The sterile individual was 11 cm. tall with a reddish or reddish-green semi-woody stem. The opposite lanceolate leaves had 12 to 16 sharp teeth and were white variegated along the veins. Mature leaves were 6.5 cm. long, 2.4 cm. wide at the broadest width, and were the broadest at 23% of the length from the base; petioles were 4 mm. long. A specimen of a leaf has been placed in the SIU herbarium.

The geographic distribution of C. maculata is restricted to the east, from southern New Hampshire to Ontario and Michigan southward to South Carolina, Georgia, and Alabama. The Pope County specimen represents a 120 mile westward extension from the range of the species in Kentucky. Another 99 mile westward disjunction is represented by a specimen recorded in Carroll County, Tennessee. The Pope County record is approximately 110 miles north of the Carroll County record.

Evidence appears to indicate recent establishment of the Pope County specimen. The stem of a mature individual of C. maculata is usually 10 to 25 cm. tall; in April our specimen was on 7.5 cm. tall and by July was 11 cm. tall. The individual did not flower which is an additional indication of its immaturity. Only one individual was found in April; however, in July a new individual was found which had apparently developed from the root system of the older plant. The Pope county individuals are in a habitat which is within the ecological amplitude of the species; therefore, reproduction and establishment of individuals would be expected in the area.

The individual of C. maculata was found in a woods dominated by white oak (Quercus alba), black oak (Q. velutina), scarlet oak (Q. coccinea) and hickory (Carya spp.). Common understory species included false dandelion (Krigia biflora), dittany (Cunila origanoides), solomon's seal (Polygonatum biflorum), false foxglove (Gerardia flava), and wild licorice (Galium circaezans). Within its range, spotted wintergreen is found in upland conifer and hardwood forests.

TRANSACTIONS, ILL. STATE ACAD. SCI.
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A SOUTHERN RECORD FOR SISYRINCHIUM CAMPESTRE BICKN. IN ILLINOIS

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While conducting a phytosociological study during the spring of 1973, a new species of vascular plant was recorded for Southern Illinois. Two flowering individuals of the blue-eyed grass (Sisyrinchium campestre Bickn.) were found in the Williams Tower Hill area (Pope County) on a dry, south facing, exposed site. The specimen collected for the SIU Herbarium is pale green with leaves and stems 1 to 1.5 mm. broad and stems up to 35 cm. tall. The single spathe is sessile with an outer margin free to the base; the perianth is blue.

In Illinois, S. campestre is found in north-western and west-central counties extending south to Madison County on the west. The Southern Illinois record is approximately 120 miles disjunct from the Central Illinois distribution and approximately 70 miles disjunct from its range from Perry County, Missouri.

The species is normally restricted to prairie habitats; however, in Pope County it was found as an understory plant in dry oak woods of low stature composed predominantly of post oak (Quercus stellata), blackjack oak (Q. marilandica), hickory (Carya spp.), and white oak (Q. alba). The most common understory species included curly grass (Danthonia spicata), pussytoes (Antennaria plantaginifolia), broomsedge (Andropogon virginicus), sunflower (Helianthus divaricatus), and false dandelion (Krigia dandelion).

The diameter-size class distribution of mature trees, presence of very large, dead trees, and relatively dense seedling and sapling strata suggest that a prairie-oak savannah community may have once occupied the site. The oak savannah community, also called oak-hickory barrens, was described by Peck (1834) as "...of mixed characters, uniting forest and prairie. The timber is generally scattering, of a rough and stunted appearance..." Curtis (1959) states that such communities were maintained by fire but with the cessation of fires in the middle 1800's, they rapidly changed into oak woodland. Additional evidence for past prairie occupancy of the site is found in the presence of other common prairie species such as spiderwort (Trandescantia virginiana), sedge (Carex pensylvanica), flowering spurge (Euphorbia corollata), sunflower (Helianthus divaricatus), prairie parsley (Polytaenia nuttallii),

and downy phlox (Phlox pilosa).

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COMPARATIVE STUDY OF THE VENOMS OF CROTALIDAE, ELAPIDAE, VIPERIDAE AND BOIGINAE

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ABSTRACT. Venoms of rear-fanged species were compared with other venoms by cellulose-acetate electrophoresis. The venoms of rear-fanged species and subspecies are as complex as the venoms of Crotalidae, Elapidae and Viperidae in regards to numbers of protein components and spectrum of electrophoretic mobilities. Similarities and differences exist between venoms of families genera, species and subspecies. The electrophoretic pattern for a given rear-fanged species' or subspecies' venom is characteristic for that species or subspecies. At pH 8.8 all proteins except three were cationic. There was no correlation between venom complexity and complexity of venom delivery apparatus.

Considerable work has been done on analyzing and comparing the venom proteins of various species of Crotalidae, Elapidae and Viperidae. Bertke, et al. (1966), presented comparisons of Crotalidae and Elapidae by use of starch-gel electrophoresis. A qualitative analysis of Crotalidae and Elapidae venoms by use of disc electrophoresis was published by Basu, et al. (1969). An intraspecific comparison of cobra (Naja) venom was reported by Tu and Ganthavorn (1968), using immunological methods and polyacetate electrophoresis. Slotta, et al. (1966), obtained excellent results with cobra (Naja naja) venom using cellulose-polyacetate electrophoresis. Extensive work on Crotalidae venom has been presented by Fiero, et al. (1972); Basu, et al. (1969); Bonilla and Horner (1969); and Dubnoff and Russell (1970). Viperidae venom has been studied by Dimitrov (1971); Devi, et al. (1970); Ohsaka, et al. (1970); and Dimitrov (1971).

Notwithstanding, little or no work has been done on the venomous secretions of the rear-fanged (opisthoglypha) snakes of the subfamily Boiginae. With the exception of the boomslang, Dispholidus typus (Pope, 1958) and the African twig snake, Thelotornis kirtlandi (Fitzsimons, 1962), these snakes are not considered dangerous to humans, but they do possess toxic secretions which are at least capable of killing or immobilizing small prey.

Previous workers, Bertke, et al. (1966), Tu and Ganthavorn (1968), Bonilla and Horner (1969), and Basu, et al. (1969) suggested that venom constituents were characteristic for a given species or subspecies, and could be used as a method for classification. It was the purpose of this comparative study to determine if the uniqueness of venom components were not only true for front-fanged species of the families Crotalidae, Elapidae and Viperidae, but also for the rear-fanged species and subspecies of the subfamily Boiginae.

MATERIALS AND METHODS

Lyophilized venoms of the following species were obtained commercially from the Miami Serpentarium Laboratories; Boiginae: Boiga irregularis, Dispholidus typus, Leptodiera annulata annulata; Leptodiera annulata rhombifera; Crotalidae: Crotalus adamanteus; Elapidae: Naja naja naja; and Viperidae: Causus rhombeatus. Also incorporated into the study was venom from a specimen of Naja nigricollis collected near Nakura, Kenya, Africa. The venom was obtained from the glass front of its cage and air dried. Air dried venom from a specimen of Agkistrodon piscivorous leucostoma collected near Pine Hills, Illinois, USA was also used to represent Crotalidae. All lyophilized and air dried venoms were reconstituted with double distilled water to yield 1 mg/ml solutions with the exception of that from Dispholidus typus (used as a 200 mg/ml solution), and Boiga irregularis and Agkistrodon piscivorous leucostoma which were represented by only trace amounts.

Cellulose polyacetate strips (Sepraphore III) were used as the supporting media in conjunction with the Gelman electrophoresis apparatus. All electrophoresis was carried out at 280 V for forty-five minutes using a 0.05M Tris-barbital sodium buffer, pH 8.8. Four strips were placed in the electrophoresis chamber simultaneously, thus giving a current of 3 mA through each strip. After electrophoresis was complete, the strips were stained for ten minutes in Ponceau S stain for protein, and decolorized in three successive baths of 5.0% acetic acid. The strips were then dehydrated in two baths of absolute methanol and cleared in 13.0% alcoholic-acetic acid. The clear polyacetate strips, mounted on glass slides, were then placed in a scanning densitometer (Gelman Instrument Company) in order to obtain accurate graphic representation of the protein fractions that were present on the strips. The scanning densitometer was equipped with an integrator which allowed the determination of the per cent protein component of the total protein. Each protein fraction of a venom was then plotted on a per cent scale of migration to allow for comparison of the venom samples.

In order to ascertain the extent to which the mobility patterns can be compared to one another, venoms of two species were combined and then separated by electrophoresis. The resulting patterns were then compared to the individual patterns.

RESULTS

Most of the protein components of the venoms migrated to the cathode at pH 8.8, with the exception of an anionic fraction in A.p. leucostoma venom and two immobile proteins. Variations in the concentration of each component (i.e. intensity of stain) are reflected in the width of the black bands in Fig. 1.

The densitometric scan of N. n. naja venom exhibited nine distinct components. The sixth component consistently had the highest concentration (36%) and the leading (ninth) component was unique among the venoms studied. All thirteen samples of this venom produced similar electrophoretic patterns.

Electrophoresis of N. nigricollis venom resulted in ten components being separated. A total of eight samples were electrophoretically separated. The leading fraction was always the most concentrated (25%) and consistently pro-

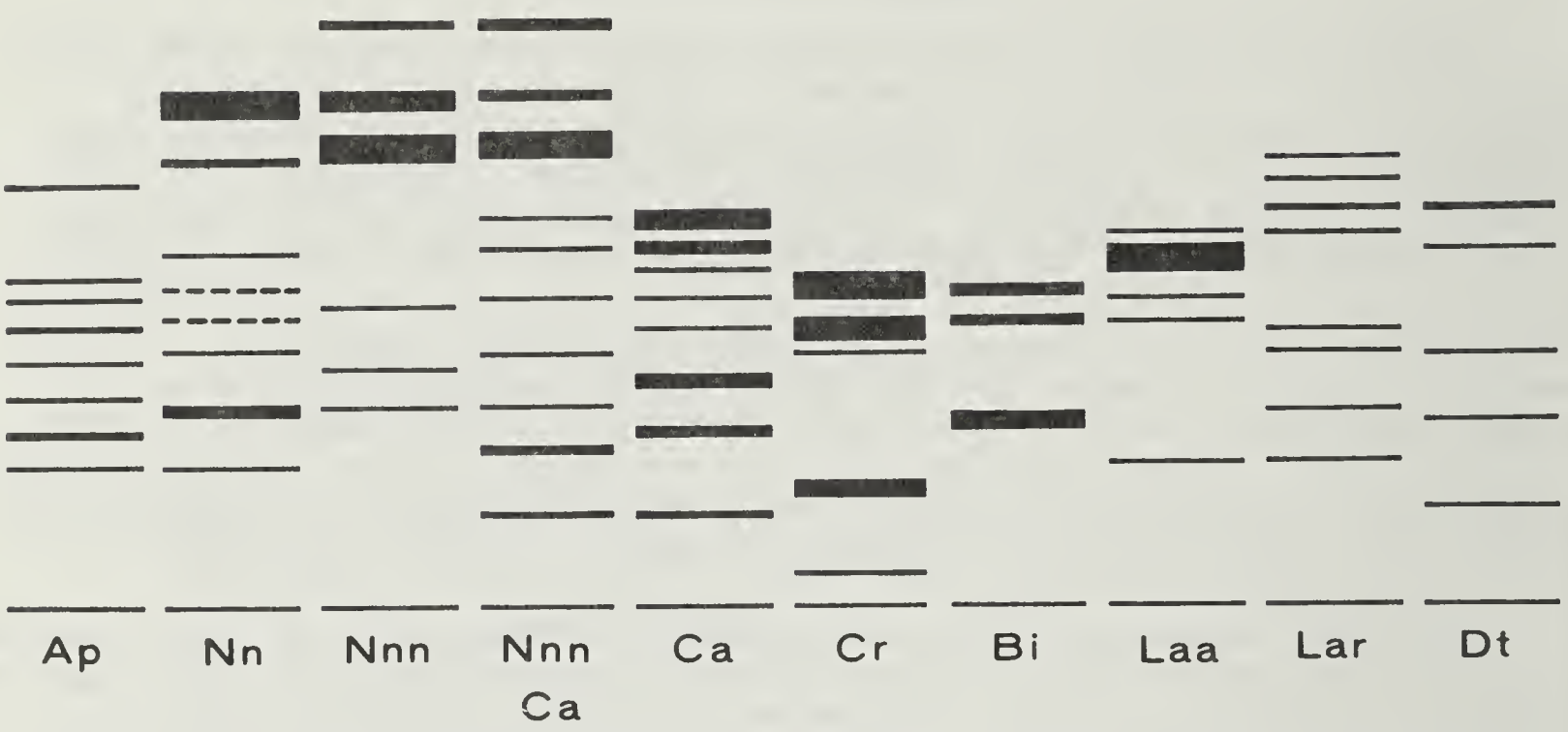

Figure 1. Diagram of electrophoretic patterns of venoms. Electrophoresed strips were lined up, overlain with tracing paper, and lines drawn to correspond to protein fractions. Densitometer scans were used to increase width of line to reflect actual concentration. Patterns are labeled at origin to correspond to following: Ap=Agkistrodon piscivorous leucostoma; Nn=Naja nigricollis; Nnn=Naja naja naja; Ca=Crotalis adamanteus; Cr=Causus rhombeatus; Bi=Boiga irregularis; Laa=Leptodiera annulata annulata; Lar=Leptodiera annulata rhombifera; and Dt=Dispholidus typus.

duced an irregular pattern on the cellulose polyacetate strip. A very broad low concentrated (11.0%) trailing fraction was present.

Ten samples of C. adamanteus were electrophoresed with all of them exhibiting nine components of relatively uniform width. The first and fifth bands were the most concentrated fractions representing 16.5% and 19.6% of the total proteins. The patterns of C. adamanteus at no time produced the three leading components found on the N. n. naja strips. Also, the wide, low concentrated trailing fraction found in N. nigricollis, C. rhombeatus and D. typus was never present.

Venom proteins of A. p. leucostoma were separated and resulted in the only anionic fraction found among the venoms studied. A total of nine protein components were distinguished in all four samples, with the second cationic fraction having the greatest concentration (22.4%).

Several fractions were separated from each of ten samples of C. rhombeatus venom. The second component was the most concentrated (33.3%) in all cases. The broad, low concentrated trailing band formed in N. nigricollis and D. typus was consistently present, but comprised of three minor components when scanned by the densitometer.

The venom of D. typus produced an electrophoretic pattern with all components staining very lightly. Fourteen samples were analyzed with seven com-

ponents being detected by the densitometer. A broad, third band was always the most concentrated fraction, usually approximating fifty per cent of the total protein. A broad trailing component was visualized on the polyacetate strip, but upon densitometric scan it was recorded as two components.

The electrophoretic pattern of all four B. irregularis venom samples exhibited three fractions. The third fraction was consistently the most concentrated component, making up 41.8% of the total venom protein.

Electrophoresis of L. a. annulata venom resulted in six protein fractions. In all three samples, the fourth component was most concentrated (24.6%), although the leading (sixth) fraction also approached this value (22.6%).

The venom of L. a. rhombifera separated into nine components. In the three samples analyzed, the fourth and eighth components were the most concentrated with values of 17.4% and 16.1% respectively.

Electrophoretic results of the composite N. n. naja and C. adamanteus venom exhibited sixteen fractions. All fractions, except the twelfth, individually made up only small portions of the total protein content of the venom. The twelfth component with a value of 17.4% was the only protein fraction having a large percentage of total protein value. All protein fractions were cationic. An interspecific comparison was then made. In comparing all of the venoms, there was a total of seventy proteins which were determined by their respective distances of migration on the polyacetate strips. Twenty-one of the seventy proteins had migration distances that were common among two or more species.

DISCUSSION

Other workers, Bau, et al. (1969), Bonilla, et al. (1969), Bertke, et al. (1966), and Tu and Ganthavorn (1968) have found that the electrophoretic patterns of snake venoms are characteristic for other than rear-fanged species. The results of this study suggest that rear-fanged species also have characteristic electrophoretic patterns and are of equal complexity. Most of the proteins of the venoms in this study migrated to the cathode, thus their isoelectric points must be higher than pH 8.8. Two proteins did not migrate, consequently their isoelectric points were approximately pH 8.8, and one protein was anionic in its migration, therefore its isoelectric point was lower than pH 8.8.

The electrophoretic pattern obtained for N. n. naja venom closely agreed with that reported by Slotta, et al. (1966), in that nine cationic protein components were produced. Basu, et al. (1969) separated thirteen cationic fractions using disc gel electrophoresis at pH 4.4. Upon comparing venom of N. n. naja with other venoms, it appeared that the leading (ninth) component was not present in any of the other venoms analyzed and that the protein fractions of N. n. naja were more mobile than most protein of other venoms. Tu and Ganthavorn (1968), using cellulose polyacetate electrophoresis, compared venoms of N. n. atra and N. n. siamensis and found them to be similar but not identical. In comparing the patterns of N. n. naja obtained in this study to N. n. atra and N. n. siamensis it was found that there were close similarities, especially

between N. n. naja and N. n. atra. The venom of N. n. naja had one component similar to A. p. leucostoma, one fraction in common with C. adamanteus, one in common with C. rhombeatus, one component similar to a component in N. nigricollis venom.

The pattern for N. nigricollis venom was somewhat similar to N. n. naja. The highly concentrated sixth component of N. n. naja did not appear to be present in the N. nigricollis venom. Similarly, the highly concentrated leading fraction of N. nigricollis was not present on N. n. naja venom. However, the seventh N. nigricollis fraction seemed similar in migration distance to the sixth N. n. naja fraction. The N. nigricollis venom did not appear to have any fractions in common with the C. adamanteus venom. The seventh component of N. nigricollis appeared as the fourth fraction in C. rhombeatus venom. In general, the electrophoretic pattern of N. nigricollis venom exhibited a wide spectrum of mobilities with the majority of the protein fraction being in the more mobile portion.

The electrophoretic pattern for C. adamanteus venom revealed ten cationic protein fractions. Basu, et al. (1969), using disc gel electrophoresis, obtained thirteen fractions most of which were anionic at pH 8.3. The pattern for C. adamanteus venom showed that none of the more highly charged fractions of the Naja species were present. Two protein fractions of the C. adamanteus venom were similar in mobilities to two fractions of C. rhombeatus venom. The fourth, seventh and ninth C. adamanteus fractions were similar in migration distances to the second, fifth and seventh cationic fractions of A. p. leucostoma venom, respectively. The proteins of C. adamanteus venom were of intermediate mobilities with the bulk of the fractions being slightly toward the lighter end of the range.

The electrophoresis of A. p. leucostoma venom resulted in one anionic fraction, and eight cationic fractions. Although Agkistrodon is a Crotalidae like Crotalus, the venoms were not noticeably similar and had only three components in common. In comparing the Agkistrodon venom with the venom of the viper, C. rhombeatus, it was found that the sixth cationic Agkistrodon component had an equal migration distance to the fourth component of C. rhombeatus venom.

The venom of C. rhombeatus produced seven cationic fractions with intermediate mobilities, but most occurred at a heavier end of the range than those of Crotalus.

In analyzing the venoms of the rear-fanged species one finds that, except for the venom of Boiga irregularis, they are like those of other venomous species in that all the venoms have complex protein compositions. The protein constituents of the rear-fanged species, for the most part, covered nearly as wide a spectrum of electrophoretic mobilities as did the venoms of the major groups of poisonous snakes.

The three protein fractions of Boiga irregularis venom had intermediate electrophoretic mobilities with the leading fraction accounting for 41.8% of the total venom protein. By analysis of migration distances the Boiga venom and the venom of A. p. leucostoma had one component with similar migration distances as did the Boiga and N. nigricollis venom. The first and third Boiga fractions and the third and fourth L. a. annulata fractions, respectively,

had corresponding migration distances.

Analysis of the two Leptodiera subspecies revealed few similarities in venom proteins at the subspecific level as was noted by Tu and Ganthavorn (1968). The venom of L. a. rhombifera contained the second highest number (nine) of protein components of all venoms studied. The nine components represented a wide spectrum of mobilities with the fourth and eighth fractions making up 17.4% and 16.1% of the total venom protein. The venom of L. a. annulata separated into six fractions. The most concentrated fractions were the fourth and sixth components with 24.6% and 22.6% respectively. Both Leptodiera subspecies had a non-mobile fraction with a migration distance similar to a component of N. n. naja, while the eighth C. adamanteus fraction was equal in migration distance to the sixth fraction of L. a. annulata. The fourth L. a. annulata component apparently migrated as did the fourth of A. p. leucostoma. In comparing L. a. annulata to D. typus, one common fraction was found.

The venom of L. a. rhombifera contained three protein fractions that were similar to ones in the N. n. naja venom, and contained one which appeared common to the N. nigricollis venom. L. a. rhombifera and C. rhombeatus venoms had one common fraction. The leading protein component of C. adamanteus coincided with the fifth fraction of the L. a. rhombifera venom. Two common components were found between L. a. rhombifera and D. typus venoms.

The venom of D. typus evidently contained less total protein than the other venoms as was determined by the faint staining of the cellulose polyacetate strips. Seven protein fractions were discerned by densitometric scanning, with a very wide third band representing forty-eight per cent of the total protein. The densitometer registered the first side band on the cellulose polyacetate strip as two separate fractions. The separation of this region into two separate bands may be due to the high sensitivity to which the scanner was adjusted. Nevertheless these two bands correspond to two bands previously noted in N. nigricollis and C. rhombeatus. The venom of D. typus had one protein fraction which corresponded to one of the C. rhombeatus protein fractions. The venom of C. adamanteus and D. typus had two fractions on common and D. typus and A. p. leucostoma venoms had one common fraction. D. typus and N. nigricollis had one common component.

The analysis of the N. n. naja - C. adamanteus venom pattern provided evidence to support the validity of the methods used to compare the venom samples. The N. n. naja - C. adamanteus pattern showed fourteen components, most of which had corresponding counterparts in the individual N. n. naja and C. adamanteus patterns. Five of the eight C. adamanteus fractions appeared in the composite patterns, and the five of the eight N. n. naja fractions were found in the composite pattern. Four of the components of the composite separation did not have components with similar migration distances in the individual patterns. With the exception of the two heavy fractions, these unaccounted for fractions had migration distances that were fairly close to fractions of the individual venom patterns. Interactions between venom constituents may have caused changes in weight and charge of the protein molecules and thus changed the electrophoretic mobilities of the protein and, hence. the inability to match them exactly with a fraction in the individual patterns.

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Ascaris sp. (probably A. columnaris). This nematode also has been reported from P. lotor in Iowa (Morgan and Waller, 1940), Washington (McNeil and Krogsdale, 1953) and Georgia (Babero and Shepperson, 1958).

Physaloptera rara Hall and Wigdor, 1918

This nematode was encountered as a single infection in 5 raccoons and as a mixed infection in 20 raccoons. Hosts infected with this species contained large numbers of specimens in the stomach along with a few nematodes in the anterior portion of the small intestine. Leigh (1940) recovered 63 specimens of Physaloptera turgida Rudolphi, 1819, from a single raccoon in northern Illinois. Morgan (1941) re-examined Leigh's specimens and reported that they appeared to be P. rara. Physaloptera rara has been reported from raccoons in Wisconsin (Morgan, 1941; Schiller and Morgan, 1949), Iowa (Morgan, 1942), Georgia (Babero and Shepperson, 1958; Sawyer, 1958), South Carolina (Harkema and Miller, 1962), and North Carolina, South Carolina, Georgia and Virginia (Harkema and Miller, 1964).

Placoconus lotoris (Schwartz, 1925) Webster, 1956 (=Unicinaria lotoris Schwartz, 1925; Arthrocephalus lotoris (Schwartz, 1925) Chandler, 1942.

This hookworm occurred only as a mixed infection. Ortlepp (1925) established the genus Arthrocephalus with A. gambiensis from an African mongoose as type. Later, Schwartz (1925) described Uncinaria lotoris, a hookworm from a raccoon taken in Maryland. Chandler (1942) transferred this species to Arthrocephalus. Because of differences in the morphology of the buccal capsules of A. gambiensis and A. lotoris, Webster (1956) transferred A.lotoris to a new genus Placoconus. In a careful study of the two genera Arthrocephalus and Placoconus, Balasingam (1964) provided further evidence to support Webster's view. Placoconus lotoris has been reported from Procyon lotor in Texas (Chandler, 1942), Michigan (Stuewer, 1943), Washington (McNeil and Krogsdale, 1953), Oregon (Senger and Neiland, 1955), Georgia (Babero and Shepperson, 1958; Jordan and Hayes, 1959), Michigan (Schultz, 1962), North Carolina, South Carolina, Georgia and Virginia (Harkema and Miller, 1964), and Alabama (Johnson, 1970). Leigh (1940) reported Arthrocephalus sp. (probably Placoconus lotoris) from two raccoons in northern Illinois.

Gnathostoma procyonis Chandler, 1942

This species occurred only as a mixed infection. Specimens were found attached to large nodules in the stomach wall resulting in marked hypertrophy. Other localities from which G. procyonis has been reported include: Texas (Chandler, 1942), Georgia (Babero and Shepperson, 1958; Jordan and Hayes, 1959), Louisians (Ash, 1962), North Carolina, South Carolina, Georgia, Florida and Virginia (Harkema and Miller, 1964) and Alabama (Johnson, 1970). The occurrence of G. procyonis in raccoons from

Illinois constitutes a new locality record.

Trematodes

Fibricola cratera Barker and Noll, 1915

Only two species of trematodes were encountered in the present study and both were diplostomids. One of these, Fibricola cratera, was previously reported as Fibricola texensis from raccoons in Texas (Chandler, 1942), Georgia (Babero and Shepperson, 1958), and South Carolina (Harkema and Miller, 1962). According to Harkema and Miller (1964), subsequent studies of their specimens and the life history investigations by Cuckler (1940), Leigh (1954), and Ulmer (1955) indicate that F. texensis is a synonym of F. cratera. Other reports of F. cratera in raccoons include those of Morgan and Waller (1940) from Iowa and Harkema and Miller (1964) from South Carolina, North Carolina and Florida. In the present study, F. cratera occurred as a mixed infection. The occurrence of this fluke in raccoons from Illinois constitutes a new distribution record.

Pharyngostomoides adenocephala Beckerdite, Miller and Harkema, 1971.

Pharyngostomoides adenocephala was the second diplostomid fluke encountered. This fluke occurred only as a mixed infection. Two species of Pharyngostomoides have been described from P. lotor. Pharyngostomoides procyonis was first described by Harkema (1942) from raccoons in North Carolina and subsequently reported from raccoons in east Texas by Chandler(1942). The second species, Pharyngostomoides ovalis, was described by Chandler and Rausch (1946) from raccoons in Michigan. Later, Dubois (1963) synonymized P. ovalis with P. procyonis. Harkema and Miller (1964) noted distinct morphological variations in adult P. procyonis recovered from raccoons in North Carolina, South Carolina, Georgia, Florida, and Virginia and suggested that further studies might reveal two species. Later, Beckerdite, Miller and Harkema (1971) demonstrated that two species of Pharyngostomoides were included in the original description of P. procyonis. A new species, P. adenocephala was described and P. procyonis redescribed. These two forms may be differentiated on the basis of size, shape, presence or absence of glands around the pseudosuckers, and presence or absence of an ejaculatory duct. Pronounced differences in the life histories of these two forms were also noted. The finding of P. adenocephala in raccoons from Illinois represents a new locality record for this parasite.

Cestoda

Mesocestoides sp.

Specimens of Mesocestoides were found only in mixed infections. Several species of Mesocestoides have been reported from raccoons and other carnivores. Mesocestoides variabilis has been

recorded from raccoons in Texas (Chandler, 1942), North Carolina, South Carolina, Georgia and Florida (Harkema and Miller, 1964), and Alabama (Johnson, 1970). Babero and Shepperson (1958) and Jordan and Hayes (1959) identified specimens from Georgia raccoons as M. lineatus. Ogren (1956) reported M. corti from Illinois raccoons.

The present taxonomic criteria for differentiating species of this genus is inadequate. Morphological differentiation is slight and variability of characteristics extensive. In a study of the genus Mesocestoides, Voge (1955a) concluded that on the basis of available data, M. corti and M. variabilis cannot be satisfactorily differentiated and proposed that both species be regarded as synonyms of M. corti. Wood and Haldeman (1957) stated that "...many of the presently named species are in reality morphological manifestations of the adaptive potential of the parasite to a variety of hosts over a wide range of localities."

Since there appears to be no well-defined criteria for separating the members of this genus, the specimens reported in the present study are tentatively identified as Mesocestoides sp.

Atriotaenia (Ershovia) procyonis (Chandler, 1942) Spassky, 1951 (= Oochoristica procyonis Chandler, 1942)

Atriotaenia procyonis was found only as mixed infections. This cestode has a wide geographic distribution. It has been reported from raccoons in Texas (Chandler, 1942), Wisconsin (Schiller and Morgan, 1949), California (Voge, 1955b), Georgia (Babero and Shepperson, 1958; Jordan and Hayes, 1959), Ohio (Gallati, 1959), Michigan (Schultz, 1962), North Carolina, South Carolina, Georgia, Florida, and Virginia (Harkema and Miller, 1964), and Alabama (Johnson, 1970). Leigh (1940) found a single raccoon from northern Illinois infected with Oochoristica sp. (probably A. procyonis).

Acanthocephala

Macracanthorhynchus ingens Linstow, 1879

Macracanthorhynchus ingens was the only acanthocephalan recovered and always occurred as a mixed infection. This species has been reported from raccoons in Texas (Chandler, 1942; Moore, 1946), Pennsylvania (Chandler and Melvin, 1951), Connecticut (Penner, 1954), Maryland (Herman, 1955), Virginia (Holloway, 1957), Georgia (Babero and Shepperson, 1958; Jordan and Hayes 1959), North Carolina, South Carolina, Georgia, and Florida (Harkema and Miller, 1964), West Virginia (Shoemaker, 1966) and Alabama (Johnson, 1970). The occurrence of M. ingens in raccoons from Illinois constitutes a new distribution record.

Table 1. - Gastrointestinal helminths found in 36 raccoons in southern Illinois

Species of helminth	Location in host	No. of animals infected	Percent infected
Nematodes			
Ascaris columnaris	Small intestine	23	63.9
Physaloptera rara	Stomach and small intestine	25	69.4
Placoconus lotoris	Small intestine	19	52.8
Gnathostoma procyonis	Stomach	2	5.6
Trematodes			
Fibricola cratera	Small intestine	6	16.7
Pharyngostomoides adenocephala	Small intestine	2	5.6
Cestodes			
Mesocestoides sp.	Small intestine	9	25.0
Atriotaenia procyonis	Small intestine	5	13.9
Acanthocephalans			
Macracanthoryhnchus ingens	Small intestine	5	13.9

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THE FIRST RECORD IN ILLINOIS OF NEZARA VIRIDULA (HEMIPTERA:PENTATOMIDAE)

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ABSTRACT. -- The discovery in Illinois of Nezara viridula (L.) is reported.

The southern green stink bug, Nezara viridula (L.), is a cosmopolitan species but limited in North America to the southern United States. Its known range extends from Virginia and Florida west to Texas (Blatchley 1926). Torre-Bueno (1912) also collected it in Brooklyn, New York, but felt it to be "an adventitious visitor." It has not been reported from Illinois.

N. viridula attacks several agricultural crops including cotton, rice, potato, oranges, sweet potato, sugarcane and soybeans (Torre-Bueno 1939). The extensive literature on this insect has recently been summarized by DeWitt and Godfrey (1972).

On 26 July 1974, we swept a 3rd instar stink bug from exposed roadside vegetation in Union Co., southern Illinois, near the La-Rue Pine Hills Ecological Area. It possessed rows of yellowish-white spots on the abdominal terga and thus, was strikingly different from all other stink bug immatures we had previously collected in southern Illinois.

The nymph was returned to the laboratory and reared in a 1-qt. mason jar, as described by McPherson (1971). It was kept in an incubator at 23.9±0.6°C and constant light of ca. 130 ft-c. Green beans (Phaseolus vulgaris L.) served as the food source.

The nymph reached the adult stage on 13 August 1974 and was identified as a ♀ N. viridula.

Since the specimen was collected as a nymph, it appears N. viridula is not only present in Illinois but is reproducing. From what is known of its distribution in the United States, Union Co. must be considered near the northern border of its range.

The specimen is deposited in the Entomology Collection, Southern Illinois University Zoology Research Museum.

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OCHETOSOMATID FLUKES OF COLUBRID SNAKES FROM ILLINOIS AND CENTRAL AMERICA

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Abstract. - Heterodon platyrhinos and Lampropeltus getulus collected in southern Illinois were found to harbor Ochetosoma elongatum and O. kansense, respectively. The finding of O. kansense in L. getulus represents a new host record. Dendrophidion percarinatus collected in the Panama Canal Zone, Central America was infected with O. kansense. Its recovery from this host in the Panama Canal Zone constitutes a new host and locality record.

In the course of parasitological examination of amphibians and reptiles from different habitats in southern Illinois, two species of ochetosomatid flukes were found in colubrid snakes collected during the summer of 1973 in southern Illinois by Richard L. Crowell. Measurements of 42 sexually mature specimens from the mouth, esophagus, stomach, and intestine of an eastern hognose snake, Heterodon platyrhinos Latreille, collected in Jackson County, fall within the range of measurements of Ochetosoma elongatum (Pratt, 1903) Goodman, 1952, as given by Dubois and Mahon (1959). Ochetosoma elongatum has been reported previously from several snake hosts including Coluber constrictor, Drymarchon corais couperi, Heterodon contortris, H. platyrhinos, and Lampropeltus getulus. This report constitutes the second record of the occurrence of O. elongatum in H. platyrhinos from Illinois.

Twenty-five sexually mature flukes from the mouth of a kingsnake, Lampropeltus getulus (Linnaeus), collected in Jackson county, were identified as Ochetosoma kansense (Crow, 1913) Skrjabin and Antipin, 1957. Previous reports on snake hosts parasitized by this species include Ancistrodon contortrix, A. mokasen, A. piscivorus, Diadophis punctatus stictogenys, Elaphe obsoleta spiloides, Heterodon platyrhinos, and Lampropeltus sp. This is the second report of this trematode from snakes in Illinois. The host, L. getulus, represents a new host record for O. kansense.

The parasitological collection of Dr. George Garoian, Department of Zoology, Southern Illinois University at Carbondale, contains numerous specimens collected from various hosts in the Panama Canal Zone, Central America. Among other helminths in the collection are several specimens of an ochetosomatid trematode taken from the mouth of Dendrophidion percarinatus (Cope), collected during July, 1959. These specimens were

identified as Ochetosoma kansense and were slightly larger than the Illinois specimens. Its recovery from D. percarinatus in the Panama Canal Zone represents a new host and locality record.

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LIPID COMPOSITION OF THE EGG SHELL OF RHIPICEPHALUS SANGUINEUS

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Abstract: Observations of thin layer chromatograms revealed the presence of wax esters, cholesteryl esters, unsaturated hydrocarbons, and lecithin in the egg shells of R. sanguineus. Observation of gas chromatograms revealed the presence of palmitate and oleate with lesser amounts of stearate and linoleate. Free fatty acids, triglycerides, paraffin, and free cholesterol were not found. Amino acids could not be detected in the lipid fraction.

Although biochemical analysis has been carried out on several varieties of insects, the investigation of Jaskoski and Butler (1971) and the present study are the first to describe the chemical components of a tick egg shell. The egg shell lipids of the tick Rhodnius prolixus are not extracted by lipid solvents and the term used to describe them by Beament (1945) is lipidized protein. Thin layer chromatography was used by Jaskoski and Butler (1971) to determine the amino acid composition of the protein component of the egg shell of R. sanguineus. The amino acids of this tick were found to be similar to those of the silkworm Bombyx mori, the cricket Acheta domesticus, and the fruit fly Drosophila melanogaster as determined by Tomita (1921), McFarlane (1962), and Wilson (1960), respectively.

Arthur (1948) reported on the layer of the egg shell of Ixodes ricinus secreted by Gene's organ. These eggs were found to rapidly shrivel and dry if they were not allowed to be covered with the secretion of Gene's organ. This layer was found to attract moisture and is presumably of a waxy nature. When the egg clusters were treated with ether, the integrity of the cluster would soon disappear.

Lees and Beament (1948) reported that a wax secretion from Gene's organ, an organ unique to the ticks, serves to waterproof the eggs. Without this secretion, the eggs of Ornithodorous moubata become completely shrivelled and hard. In other tick species such as I. ricinus, a portion of the external lipid layer was found to be secreted by the common oviduct and the vagina. By interferring with the normal process of Gene's organ in this species, partial waterproofing was still observed. The egg shell lipid layer of O. moubata when extracted with hot chloroform was found to have two fractions in a 6 to 1 ratio, a white waxy solid and a soft yellow grease. The lipid layers of O. moubata and I. ricinus measured 0.47 μ and 1.76 μ respectively.

The outer layer of the egg shell of Metatetranychus ulmi Koch is described by Beament (1951) as a hard, transparent, waxy coating of an inert lipoid material that is unsaturated in nature. This lipoid layer has a high melting point, no proteinaceous material, and its function, unlike in ticks, is not to waterproof the eggs.

The egg shells of the mite, Petrobia latens Muller were studied by Lees (1961). He described the outer wax layer as having a melting point of 165°C., insoluble in a cold benzene or chloroform, or ethanol, but soluble in hot benzene or chloroform. The carbon chain lengths probably range from 16 to 36 as in other hard insect waxes as suggested by Chibnall et al (1934) and Beament (1945).

The investigation reported here was undertaken to determine the nature of the lipids in the egg shell of Rhipicephalus sanguineus. Possible application of this kind of a study relates to tick control at a most vulnerable stage of the life cycle, the egg.

MATERIALS AND METHODS

Oviposition was induced in a fully engorged tick by the method of Kohls (from Lutz, 1937). The eggs produced were examined under the dissecting microscope and were found to measure 0.5 mm by 0.3 mm in the form of translucent red ovals.

The vacated shells of Rhipicephalus sanguineus are translucent white ovals that are split along a thickened area, the "hatching line" as described by Jaskoski and Butler (1971).

A batch of egg shells* was first cleaned of macroscopic debris by hand using two sharp dissecting probes under the dissecting microscope. They were weighed on an analytical balance at 6 mg. The egg shells were fragmented in 100 ml triple distilled water using a Sonifier Cell Disruptor** for five minutes at which time almost all of the egg shells were broken and had settled to the bottom. The egg shells were removed from the water by centrifugation, and then washed three times with triple distilled water. The small pellet of egg shell fragments produced was drained by inverting the tube and allowed to dry at room temperature for one hour. This procedure for cleaning the egg shells is a modification of the method used by Clegg and Morgan (1966) for Fasciola hepatica eggs.

*Kindly supplied by Dr. Willy Burgdorfer of the Rocky Mountain Laboratory, USPHS, Hamilton, Montana, and Dr. Gordon K. Sweatman, Department of Tropical Health, American University of Beirut, Lebanon.

**Heat Systems Company, Melville, L.I., New York.

The clean dry egg shells were resuspended in 25 ml anhydrous ether and transferred to a 125 ml Erlenmeyer flask. This suspension was shaken on a Burrell Wrist-Action Shaker for ten minutes and the ether fraction was decanted and stored in the refrigerator at 3°C. A fresh 25 ml portion of ether was added to the egg shells and again shaken for 10 minutes. This ether extraction was repeated three times a day for three days, the other fractions being centrifuged, decanted and collected in a single vessel.

Further extraction of the lipid layer was made using the method of Schmit and Wynne. The egg shells were soaked in 10 ml chloroform-methanol (70/30 v/v). This was then centrifuged at 2000 rpm for 10 minutes, the liquid phase being added to the ether soluble lipid fraction. This was repeated three times.

The other half of the lipid-containing solvent was prepared for gas chromatography by reduction to dryness in a 25 ml test tube using a stream of dry nitrogen. A fresh mixture of 9 ml absolute ethanol and 1 ml 33% KOH was added to the lipids to saponify them. This was then heated on a water bath for 30 minutes at 55°C. Fifty percent HCl was added to this drop by drop until the solution became acidic. The fatty acids were then extracted using 10 ml hexane three times. The hexane fraction was then washed twice with 10 ml portions of triple distilled water, and dried for 24 hours over sodium sulfate. The hexane fraction was then dried under nitrogen in a 25 ml volumetric flask. Ten ml of 5 percent perchloric acid in methanol was added and heated on a water bath for 20 minutes at 55°C. The methyl esters thus synthesized were extracted three times with 10 ml hexane-ether (50/50 v/v). The esters were washed three times with distilled water and dried again over sodium sulfate. One ml chloroform containing 50 mg C_{17} was added to the residue as an internal standard.

The gas chromatograph (Barber-Coleman flame ionization, thermal conductivity, He carrier gas at 200°C.) was programmed from 100°C. to 215°C. at 3°C./min and had a 6' column of 6 percent DEGS on 80/100 mesh Diatroport S. Two µl of the above solution was injected into the chromatograph.

Thin layer chromatography was employed to determine the lipid classes using glass plates 20x20 cm and 5x20 cm coated with a layer of Silica Gel 250 µ thick. These plates were prepared by the method of Stahl (1965).

The solvent systems used to develop the chromatograms were ethylene dichloride, acetic acid, 99:1; n-hexane, diethyl ether, acetic acid, 99:10:1; and petroleum ether, diethyl ether, acetic acid, 80:20:1. In all cases the chromatography chambers were allowed to become saturated with the solvents for 24 hours before the development of the plates. The distance of the solvent front migration was between 12 cm and 15 cm for all chromatograms.

Visualization was accomplished in most cases using the iodine vapor technique. Other methods used include charring with chromic-sulfuric acid, or spraying with 2,7-dichlorofluorescein, phosphotungstic acid, or ninhydrin.

RESULTS

Use of thin layer chromatography techniques revealed the presence of highly mobile non-polar lipids with high R_f values for the types of solvent systems used. The uppermost area in the chromatogram of the tick lipids corresponds with standard solutions of cholesteryl esters, particularly cholesteryl

oleate and cholesteryl palmitate. The lower weight cholesteryl esters have a slightly decreased mobility and do not correspond with the unknown. This region sprayed with 10 percent alcoholic phosphotungstic acid revealed a red color that indicated the presence of cholesteryl esters. Since only a fraction of this area reacted positively to phosphotungstic acid, it is certain that other lipids are present in this area.

Squalene, an unsaturated branched hydrocarbon (C_{30}), showed a high mobility corresponding with this area of the tick lipids, as well as similar tailing effects. The dark I_2 color is similar to the unknown, lending evidence that there is a high degree of unsaturation in the tick lipids. When the charring technique is used to visualize the chromatograms, both the unknown and squalene demonstrated rapid breakdown in this area.

An effort was made to test for saturated hydrocarbons, that is, long chain alkanes with strong C-H and C-C alpha bonds that are not readily attacked by hydrolysis or oxidation. These include mineral oil, lubricants, and paraffin. These saturated hydrocarbons tend to repel the I_2 visualization due to their lack of weak pi bonds and thus have a characteristic faded area that is not present in the egg shell fraction.

Natural waxes are not saturated and appear in the unknown. Pure beeswax is a mixture of waxes, the main component being myricyl palmitate. This is the fatty acid ester of myricyl alcohol and palmitic acid. Other bases for these esters can be oleic and linoleic acids which have been determined as bases for the lipids in the unknown. It is thus apparent that the uppermost area of the tick egg shell lipids corresponded with natural wax esters, cholesteryl esters, and unsaturated hydrocarbons.

Under all types of solvent systems used, lecithin was found to correspond to an area of the unknown that is somewhat less mobile than that mentioned above. Under long wave ultraviolet light, lecithin and its tailing effects exhibit a light violet color that corresponds with the tick egg shell lipids. Several sources of lecithin were used including synthetic and bovine. It is likely that the fatty acids involved are palmitic and oleic as they would be cleaved from the lecithin molecule during the preparation of the unknown for gas chromatography.

Cholesterol and other sterols were repeatedly sought in the fraction and are present in only trace amounts, if at all. The area of the chromatograms where cholesterol would appear, if present, was sprayed with phosphotungstic acid and the results were negative.

The use of TLC revealed that only trace amounts of triglycerides are in the egg shell lipids. Free fatty acids have been compared to the unknown and no indication of their presence was indicated. The unknown lipids were compared to several lipids from both classes and negative results were constant.

Spraying the unknown on the chromatogram with 0.5 percent ninhydrin revealed that no amino acids were present.

The methyl esters of the total lipid fraction of the tick egg shells as obtained by extraction and synthesis as mentioned above indicate the presence of palmitate and oleate, with smaller amounts of stearate and linoleate.

SUMMARY

1) The lipid fraction of the egg shells of Rhipicephalus sanguineus was analyzed using the techniques of thin layer and gas chromatography. The outer wax layer was separated from the inner protein or shell layers by extraction using anhydrous ether, chloroform-methol (70/30 v/v), and hexane-ether (50/50 v/v).

2) Using thin layer chromatography, it was shown that the egg shells contain wax esters, cholesteryl esters, unsaturated hydrocarbons, and lecithin.

3) By gas chromatography, palmitate and oleate with lesser amounts of stearate and linoleate were present.

4) Free fatty acids, triglycerides, paraffin, and free cholesterol were not found.

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AN ESTERASE PHENOTYPE CORRELATED WITH DISPERSAL IN MICROTUS

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Abstract.-- A strong correlation was discovered between an esterase isozyme phenotype and prairie voles, Microtus ochrogaster, that had dispersed across extensive areas of unsuitable habitat. This indicates there may be a genetic component associated with dispersal in the prairie vole.

Lidicker (1962) postulated that emigration might be a means by which a population could be regulated below its carrying capacity. He stated that there "is the possibility that a tendency to emigrate may be selected for in a given species and eventually come to play a primary role, even if an uncommon or occasional role in population regulation." Howard (1960) proposed two types of dispersers: ecological and innate. Ecological dispersers would be affected by population pressures; their dispersal would be density dependent. Innate dispersers, however, would disperse without regard to population density. Howard suggested that both ecological and innate dispersers were genetically based.

The present study was initiated to determine if a genetic difference, at the level of the enzyme phenotype, exists between dispersing and non-dispersing individuals of the prairie vole, Microtus ochrogaster. Starch gel electrophoresis of enzymes was used as a means of identifying genetic markers associated with dispersal.

Myers and Krebs (1971) and Tamarin and Krebs (1969) have examined various isozyme differences in vole populations through electrophoretic techniques. Our study emphasized identification of an enzyme marker associated with dispersal. We were not attempting to correlate such enzyme occurrence with phase of the population cycle. A disperser as defined in this study is an animal which has had to cross unsuitable habitat and not simply reoccupy a contiguous suitable habitat depopulated by trapping. We employed starch gel electrophoresis because it provides a sensitive resolution of enzyme variants. An esterase system was investigated since such systems display high levels of polymorphism and therefore are ideal for studying population variation within a species.

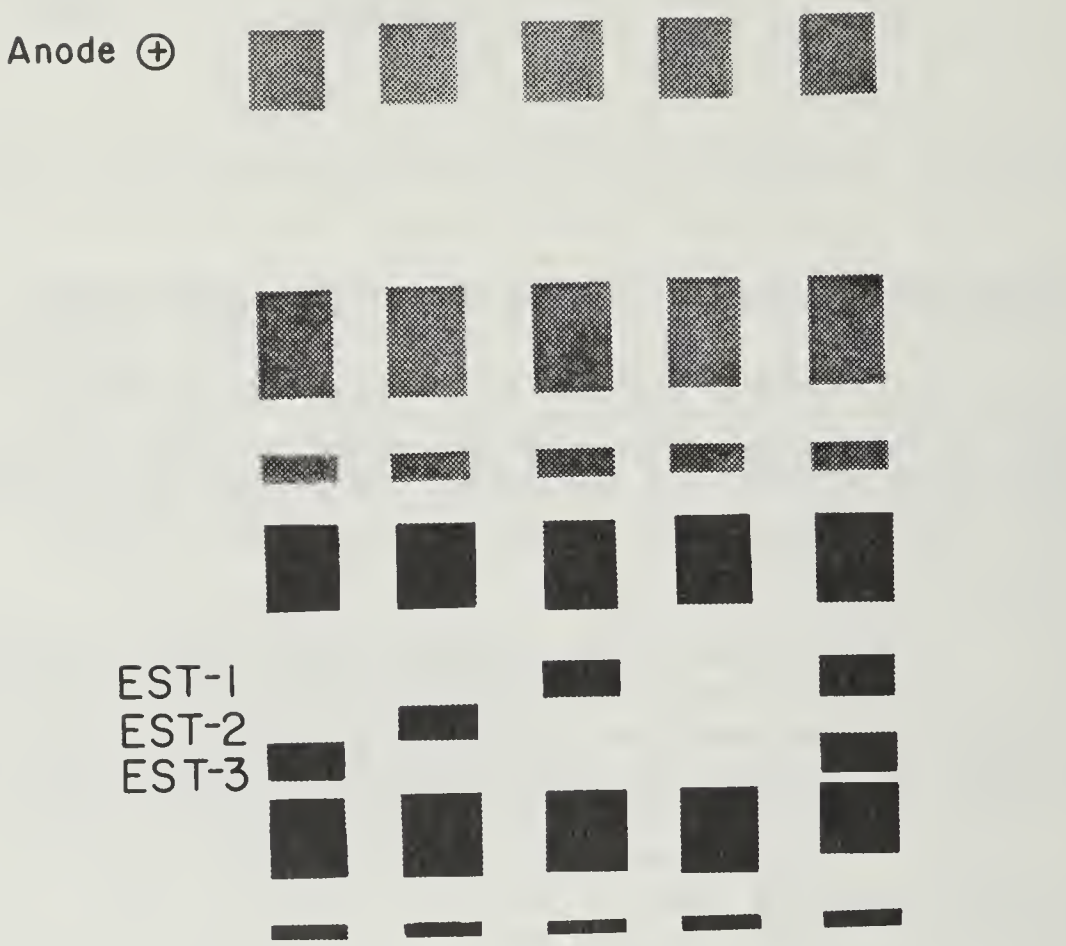

Figure 1. Esterase isozyme phenotypes observed in the Microtus ochrogaster populations studied. The esterase phenotypic designations below the zymogram refer specifically to the presence and absence of the three esterase isozymes indicated to the left as EST-1, EST-2, and EST-3.

Dispersers were obtained by first removing all resident M. ochrogaster from two isolated grassy fencerows 1.5 km S Urbana, Illinois. The voles that dispersed into these fencerows during a period of one month were live-trapped for study. These strips

of grass, approximately 2 m wide, are capable of supporting a limited number of voles. Cultivated fields, unsuitable vole habitat, extended for at least 1/2 km on all sides of the fencerows. Any dispersing individual would have had to travel at least this distance over unsuitable terrain. The fencerows were cleared of their resident populations in mid-March by first live-trapping. The fencerows were then snap-trapped for seven days; no voles were caught during the snap-trapping. We, therefore, assumed all residents had been removed; prior experience with fencerow trapping indicated all individuals should have been caught in that time.

The animals classified as dispersers were live-trapped in April, a month after the initial depopulation. This period of time was chosen to provide time for immigration, but not time for recruitment by reproduction of the early arrivals. The non-dispersal group was comprised of the 14 animals trapped in the fencerows in March plus 33 individuals sampled in a large population (8.5 ha area; 19 voles/ha) located more than 10 km from the fencerow area studied. The source of the dispersers was not located; they apparently came from patches of habitat at least 1 km from the fencerows. The spatial pattern of vole habitats was such that it was highly unlikely the "dispersers" came from one source.

Different esterase isozyme phenotypes were observed in the vole populations after starch gel electrophoresis. Blood samples were collected in heparinized capillary tubes from the cavernous sinus (Semeonoff and Robertson, 1968). The blood was then centrifuged at 15,000 g for 30 minutes at 4°C. The supernatant was subjected to electrophoresis on vertical starch gels. A discontinuous buffer system (EDTA-Borate-Tris) was employed (Boyer, et al., 1963). Electrophoresis was carried out at 4°C, at 7V/cm, for 20-28 hours. The gels were cut in half and stained for esterase activity according to Shaw and Prasad (1970).

The esterase bands are shown schematically in the zymogram shown in Figure 1. Five phenotypes were observed and scored.

A significantly ($X^2 = 12.20; <.05$) higher proportion of the dispersers possessed the EST-1 phenotype (Table 1). In addition, only 11 of 88 M. ochrogaster from a laboratory (established two years earlier with 25-30 individuals from two separate wild populations; one in the vicinity of the fencerows in this study) tested possessed the EST-1 phenotype.

The exact molecular and genetic bases of these esterase phenotypes has not yet been elucidated. However, the discrete nature of the electrophoretic mobility differences suggests a simple Mendelian basis, probably several alleles at one esterase locus. Laboratory reared M. ochrogaster did not undergo a change in their isozyme phenotypes over the life span of the individuals studied. Furthermore, there was no significant correlation between sex and esterase phenotype ($X^2 = 2.93$, df, 3).

Table 1.-- Frequency of esterase phenotypes in dispersing and non-dispersing Microtus ochrogaster. Dispersers were obtained from immigrators into isolated habitats from which the residents had been removed.

Esterase Phenotype	Dispersers	Non-dispersers
Esterase - 1	11	19 (5)*
Esterase - 2	1	8 (6)
Esterase - 3	0	7 (0)
Esterase - 1-3	0	4 (0)
Null	0	9 (3)
Total	12	47 (14)

*Numbers in parentheses indicate individuals resident in the isolated habitats at the time of the removal trapping.

Because the dispersal group possessed predominately the EST-1 phenotype in contrast to the control group, there does appear to be a genetic component which is associated with dispersal in this species. At the present time it is not known what relationship the possession of the EST-1 enzyme has to dispersal in M. ochrogaster. Since relatively few dispersers were obtained in this study, the results are susceptible to the usual small sample biases. In addition, environmental or behavioral factors other than dispersal could be the selective factor, if any, involved in the high proportion of the EST-1 phenotype in dispersers. Much larger samples and more extensive analysis of possible selective factors would be necessary to establish the true correlation between the EST-1 phenotype and dispersal of this species.

If the EST-1 phenotype is associated with dispersal, it is improbable that this study has fortuitously found the "dispersal gene" or even an enzyme locus on the same chromosome with a main genetic determinant of dispersal behavior. There could be an epistatic interaction of the EST-1 allele and genetic components on separate chromosomes which are involved in dispersal behavior.

Regardless of the unanswered questions concerning the significance of the data presented here, the strong correlation between an esterase isozyme phenotype and the tendency to disperse is highly suggestive and certainly warrants future study.

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VARIATION OF THE CONTENT OF 2,4-DIHYDROXY-7-METHOXY-2H-1, 4-BENZOXAZIN-3(4H)-ONE GLUCOSIDE IN CORN (ZEA MAYS L.)

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Resistance of corn plants to stalk rot and European corn borer has been related to the quantity of 2,4-dihydroxy-7-methoxy-2H-1, 4-benzoxazin-3(4H)-one glucoside. Values calculated as µg of 6-methoxy-2-benzoxazolinone (MBOA) per gram of fresh corn tissue ranged from 14 to 394. Variations (from 18 to 32 µg MBOA per g fresh weight) observed in samples of the same genetic background grown at different time periods appear to be due to differences in the amount of heat and light received by the plant.

Some cyclic hydroxamic acids are antibiotics and all form very stable chelates with the ferric ion. They may be ubiquitous in aerobic microorganisms, and are produced in large quantities under iron-deficient grown conditions (Emery, 1971).

One group of cyclic hydroxamic acids, the 2,4-dihydroxy-2H-1,4-benzoxazin-3(4H)-one glucosides, are found in corn, wheat, rye, and barley. After removal of the D-glucose unit, the free aglycons are converted into 2(3)-benzoxazolinones which are antifungal compounds. For example, 2,4-dihydroxy-7-methoxy-2H-1,4-benzoxazin-3(4H)-one (DIMBOA) can be converted into 6-methoxy-2-benzoxazolinone (MBOA), and the concentration of both has been related to the resistance of corn plants to stalk rot (BeMiller, 1965) and to the European corn borer (Klun, 1966, 1969, 1970; Loomis, 1957; Smissman, 1957, 1957a) and the resistance of wheat plants to stem rust (Elnaghy, 1962).

Various methods have been used for measurement of these compounds (TABLE 1). It is difficult to compare reported amounts because of differences in tissue samples used. Some workers used fresh plants, others used dried plants; some used the entire plant, others used only portions of the plant; and various sizes and genetic backgrounds have been used. Final

results have been variously reported as content of DIMBOA, DIMBOA glucoside, and MBOA.

In spite of the difficulties, an attempt was made to compare values reported for corn tissue (Scism, 1972). The various methods and reported values are given in TABLE 1. In this table, values from the various sources have been changed to µg of MBOA per gram of fresh corn tissue by appropriate conversions of the values reported. Dry sample weights were converted to a fresh weight basis by arbitrarily assuming fresh samples to be 90% water. It is obvious that the reported values differ greatly.

Age is a factor that influences the amount of DIMBOA glucoside found in corn plants, for 5 times as much DIMBOA per gram of fresh weight was found in 14-day old seedlings as in 2-month-old plants (Virtanen, 1963).

An infrared method for the determination of 2,4-dihydroxy-2H-1,4-benzoxazin-3(4H)-one glucosides in plant tissues has been developed in this laboratory (Scism, 1974). The method involves freezing and thawing of tissue samples to allow enzyme-catalyzed cleavage of the glucosides, fragmentation, extraction of the released aglycons, removal of chlorophyll, conversion of the 2,4-dihydroxy-2H-1,4-benzoxazin-3(4H)-ones to the more stable 2(3)-benzoxazolinones, removal of the 2(3)-benzoxazolinones by extraction, and quantitative ir measurement of the 2(3)-benzoxazolinones in methylene chloride solution.

In connection with this study, precision of the ir method was determined using a group of 10 replicates of a B37 X B14 population of corn seedlings grown for 14 days in August 1971 (Scism, 1974). When results of this study were compared with those from other populations grown in the greenhouse for other periods of time between August and December 1971, considerable variation in the µg of MBOA per g of fresh tissue was found (range 180-316; mean 246). In general, the later in the year the corn was planted, the longer the period required for the plants to reach a height of 45-60 cm and the lower the MBOA content.

The differences in MBOA content might be related to differences in temperature and light experienced by the plants during their growth period. Seedlings grown in the dark exhibited lower levels of MBOA than seedlings grown in the light, but exposure of the seedlings grown in the dark to light for a period prior to sample collection gave a fourfold increase in MBOA (Loomis, 1957).

A relationship between the time of planting and susceptibility to stalk rot in corn has been noted (Pappelis, 1966). Corn planted in cooler weather (1 April, 15 May) showed more

stalk rot than corn planted later (15 June, 1 July). When the cold, wet conditions under which corn had been damaged by atrazine (to which it is normally tolerant) were simulated, it was found that root extracts from plants grown at lower temperatures (10°C to 15°C) had a decreased capacity to hydroxylate atrazine, compared to root extracts from plants grown at higher temperatures (25°C to 30°C), because of decreased amounts of benzoxazinones in roots of the plants grown at the lower temperatures (Thompson, 1970).

Thus, comparisons of the DIMBOA glucoside content found in different corn populations should be made from samples which have been grown under the same conditions, for it appears that samples of a single genetic background will have different contents of DIMBOA glucoside if they have different histories with respect to temperature and illumination. Seeds should be planted at the same time, in the same place; plants should experience the same growing conditions and be harvested at the same time, and the same portions of the plant should be taken for samples if valid comparisons and genetic selections are to be made.

Further research relating the amount of heat and light received by corn plants and the amount of available iron to their content of DIMBOA glucoside seems to be needed.

Table 1. -- Comparison of Selected Reported Values for DIMBOA Glucoside Content of Corn Tissue[a]

Substance reported	Corn type	Technique	Plant part	Quantity[b] as MBOA	Ref.
MBOA	W210D W204	isolation	tops	14-110	Loomis, 1957
DIMBOA		isolation	tops	150	Wahlroos, 1959
DIMBOA glucoside		isolation	tops	394[c]	Wahlroos, 1959
MBOA	R105-204 R105-206	fluorescence	whorl	180 50	Bowman, 1968
MBOA	C.I.31A Oh 45 WF9 B37 B14	isotopic dilution	whorl	214 100 16 20 32	Klun, 1966
DIMBOA	C.I.31A X B49 W22 X R101 B37 X B14	isotopic dilution	whorl	170 54 28	Klun, 1970
MBOA	B37 X B14	infrared	seedlings	32	Scism, 1974
MBOA		isolation	tops	15	Smissman, 1957
DIMBOA		isolation	etiolated shoots	390	Hamilton 1962

Table 1. (continued)

Substance reported	Corn type	Technique	Plant part	Quantity[b] as MBOA	Ref.
DIMBOA	Early Albert	isolation		70-350	Virtanen, 1963
DIMBOA	C.I.31A	isolation	etiolated tops	150	Tipton, 1967
MBOA	C.I.31A	isotopic dilution	whorl	394	Klun, 1969
	WFO			50	

[a]When values were reported for different plant sizes and cultivars, the value for the plant size closest to that used by us was chosen, as were values for the cultivars which gave the extreme limits.

[b]µg per g of corn (fresh weight).

[c]Known to be quite impure.

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TRANSITORIZED POTENTIOSTAT FOR NONAQUEOUS REDUCTIONS

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An inexpensive high current--high voltage potentiostat for electrolytic reductions in nonaqueous solvents has been constructed in this laboratory. The goal was to construct a potentiostat that would reduce a 10 to 15 milliequivalent-sample in one working day (8 hrs.). We started with the basic solid-state circuit of Tackett and Knowles (Tackett, 1966), which could deliver only 16 ma through a 500 ohm load, and added a second power supply with a full-wave rectifier and filtering circuit plus three current boosting field-effect power transitors. With the additional power transitors, we could produce a 120 ma current through a 600 ohm load resistance.

Nonaqueous polarographic reductions are common techniques which have been extensively studied by numerous investigators including Zuman (Zuman, 1964 & 1970) and Wawzonek (Wawzonek, 1955) who have contributed a great deal to advancing this field to its present day renaissance. Coupled with organic polarography, a chemist is often times interested in isolating a product which is predicted by the polarograms and postulated by the researcher's proposed mechanism. The controlled potential reduction at the half-wave potential of the polarogram provides the researcher with a technique which is capable of isolating and/or trapping the proposed intermediate.

Carbenes and benzyne intermediates are examples which have been generated by electrochemical means (Wawzonek, 1961; Wawzonek, 1963). Recently, in this laboratory, we have incorporated a laboratory constructed potentiostat to operate in nonaqueous systems, and studied the dimerization of difluorenylidene generated from 9,9-dichlorofluorene at a controlled reduction potential of -0.39 v (Duty, 1974).

Earlier, two investigators (Tackett, 1966) had described an inexpensive solid-state potentiostat which had a maximum voltage output of 5 volts and a maximum current output of 2 amp. Later, two potentiostats were described (Bottei, 1970) which employed an operational amplifier with a voltage booster. In addition, Bottei and Boczkowski's circuit schematics incorporated a power tube booster in one potentiostat and a power transitor booster in the other.

In this laboratory we were in need of an inexpensive high current-high voltage potentiostat for electrolytic reductions in the nonaqueous solvent dimethylformamide. The high current was desirable because we anticipated

unfavorable side reactions with extended reduction times. Our goal was to construct a potentiostat that would reduce a 10 to 15 milliequivalent sample in one working day (8 hours).

The solid-state potentiostat of Tackett and Knowles, which could meet our expense budget but not our ma current requirement, could only supply 16 ma through a 500 ohm load resistance. This was a lower resistance than we anticipated for our nonaqueous reductions (1000 ohms). With this amount of current flow, a reduction of 10 milliequivalents of compound would require at least 16 hours to complete. This low current output through high resistances is also a disadvantage of the solid state emitter-follower circuits suggested by Bottei and Boczkowski since their current capacity is increased through low resistances but does not increase through high resistances.

The Potentiostat

The wiring diagram for our potentiostat is shown in Figure 1. The circuit consists of two power supplies; one to provide voltage for the reference voltage and voltage regulation sections, and a second to provide the necessary voltage increase demanded by the nonaqueous reductions. Both power supplies are designed with conventionally regulated d.c. voltages containing full-wave rectifier and filter sections. The dashed-line area in Figure 1 includes the circuit that was adapted from Tackett and Knowles. We started with this basic solid-state circuit and added to it the second power supply including the full-wave rectifier and filter circuit plus the current boosting transistors, Q_5, Q_6, and Q_7. The output signal from the differential amplifier, transistors Q_1 and Q_2, is fed through the power transistors, Q_4, Q_5, Q_6 and Q_7. The reference voltage is set by R_4 against a standard reference electrode. The diodes, CR_{10} and CR_{11}, are zener diodes which comprise the reference voltage from which R_5 and R_6 set the limits for the reference voltage required by R_4.

The added circuit of transistors Q_5, Q_6 and Q_7 increases the current capacity of the potentiostat for operation in nonaqueous systems which have voltage 0 to 8 volts on its base produced 30 to 8 volts, respectively, on the collector. Since Q_6 is in phase with the base voltage of Q_5, transistor Q_6 changes from 0 to 90 volts when the base voltage of Q_5 changes from 0 to 8 volts. The output of transistor Q_6 is applied to the base of Q_7 which is an emitter-follower output circuit. Consequently, with the addition of the circuit containing transistors Q_5, Q_6 and Q_7, a reduction of 10 milliequivalents of compound would require only 2 hours with a load resistance of 500 ohms instead (see Table I) of the previously calculated 16 hours for the Tackett and Knowles circuit.

The circuit of transistors Q_5, Q_6 and Q_7 had current capacities through various load resistances as given in Table I. With the reference voltage set at approximately 1 volt, a change of $\pm$ 0.01 volt produces a 1 volt - 2 ma change through 600, 400 or 200 ohm loads. The ripple voltage was $\pm$ 0.01 volt with 60 ma flowing through a 600 ohm load as measured with a Heath oscilloscope Model EUW-25.

FIGURE 1
Solid-State POTENTIOSTAT

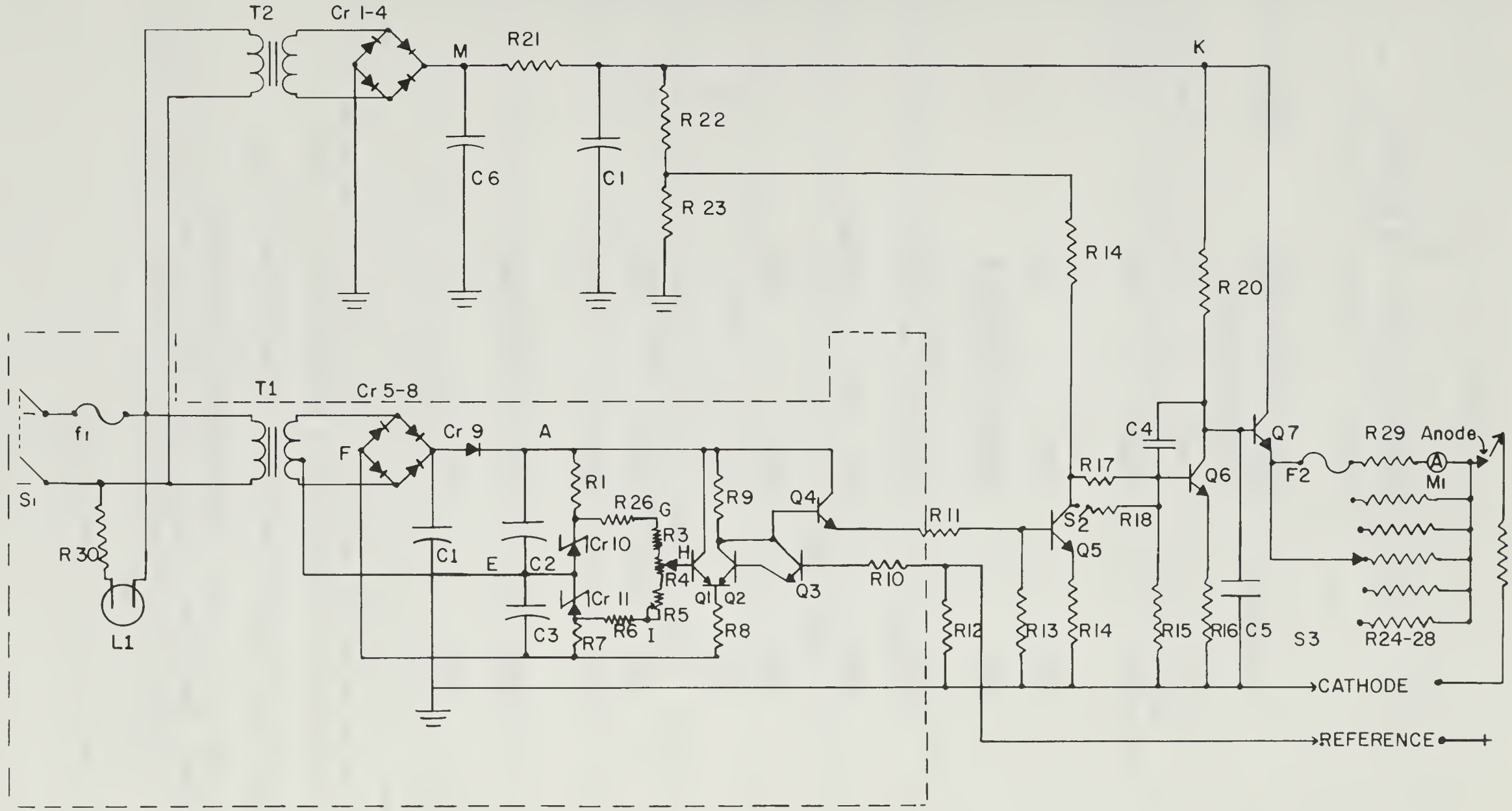

Table I

Load Resistance, Current and Voltage

Range[a]	Load (ohms)[b]	Output Current (ma)[c]		Output Voltage (volts)[d]	
		Max	Min	Max	Min
1	1000	90	22	90	22
2	1000	90	0	90	0
1	300	100	24	80	19.2
2	800	100	0	80	0
1	600	120	33	72	19.8
2	600	120	0	72	0
1	400	180	42	72	16.6
2	400	180	0	72	0
1	200	280	100	56	20
2	200	280	1	56	0.2
1	100	400	180	39	18
2	100	400	2	39	0.4

[a] The range switch (S_2 in Figure 1) was added in the event that the current through the cell can not be allowed to go to zero.

[b] Obtained by using 200 ohm, 10 watt and 10% resistors.

[c] Measured with external milliammeter (Weston Model 980 Mark II). Max Value Ref. electrode voltage is less than set reference voltage (set by R_4). Min Value is obtained when Ref. electrode voltage is greater than set reference voltage.

[d] Measured with Heath EUW-24 VTVM.

A complete parts list for the potentiostat is given in Table II. The total cost of the parts taken from current catalogs is less than $225. As can be seen from the schematic, a vacuum tube voltmeter (VTVM) is required to complete the potentiostat. If a school does not have a VTVM available, this would be an additional expense to consider.

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Table II

Parts List for Potentiostat

R1, R7	1 K, ½ W, 5%	C1	18,000 mf, 25 v
R2	3.3 K, ½ W, 5%	C2, C3	500 mf, 30 v
R3, R4, R5	2 K, 10 turn, potentiometer	C4	0-22 mf, 200 v
R6	3.9 K, ½ W, 5%	C5, C7	100 mf, 100 v
R8	1-3 K, ½ W, 5%	C6	500 mf, 200 v
R9	5.1 K, ½ W, 5%	CR1-8	Diode Motorola HEP-170
R10	6.2 K, ½ W, 5%	CR9	IN4383
R11	15 K, ½ W, 5%	CR10, CR11	IN752
R12	22 meg, ½ W, 5%	F1	½ a Slo-Blow, 3 AG
R13, R17	10 K, ½ W, 5%	F2	1/8 a, 3 AG
R15	16 K, ½ W, 10%	L1	Pilot lamp NE-2 Neon
R14, R16	100 ohm, 2 W, 5%	M1	0-100 a meter 2 K ohm
R19, R23	10 K, 5 W, 10%	Q1-3	2N3392
R20	15 K, 10 W, 10%	Q4-5	Motorola HEP-243 Silicon NPN Med. Power (Max 1W) Collector Current 1 amp max Similar to 2N2108
R21	350 ohm, 12 W, 10%		
R22	15 K, 5 W, 10%		
R24	0.22 ohm, 5 W, 1%		
R25	2.2 ohm, 5 W, 1%		
R26	22 ohm, 1 W, 1%	Q6	Motorola HEP-241 Silicon NPN 20 W max. Collector Current 3 amp max. Similar to RCA 2K3026
R27	220 ohm, ½ W, 1%		
R28	2200 ohm, ½ W, 1%		
R29	20 K, ½ W, 1%		
R30	180 K, ½ W, 10%		
S1	DPDT, toggle switch	Q7	2N 1490 NPN diffused junction. Collector current 6 amp max 75 W. max
S2	SPST, toggle switch		
S3	SP6 Position, rotary switch		
T1	Transformer, 12.6 v C.T., 1-5a	T2	Transformer, 80 v C.T., 1-2a

Misc. -- 7½ x 13¼ Cabinet Allied #42F7254, Heat Sinks Allied #60F6510 and 60F650, 7 x 12 x 7 Chasis Buc #AC-408, Knobs #16 Gauge Stranded Copper Wire, Jacks Allied #47F3900, Printed Circuit Boards Allied #47F0942, and Transistor Sockets Allied #47F0262 and 47F1047.

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INTERACTION OF MAGNESIUM ION WITH PYRUVATE KINASE*

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ABSTRACT - Using the technique of gel filtration, the enzyme pyruvate kinase is shown to bind approximately 40 magnesium ions per molecule of enzyme at 25°C and pH 7.0. The intrinsic binding constant at low ionic strengths was estimated to be 4×10^4 liters/mol. No effect on the binding of Mg^{++} could be detected when Li^+ was substituted for K^+ at an ionic strength of 0.025M.

In addition to its two substrates, pyruvate kinase (ATP-pyruvate phosphotransferase, EC 2.7.1.40) requires the presence of both Mg^{++} and K^+. (Boyer and Lardy, 1942). Up to the present time, no complete explanation of the role played by either of the two metal ions has been given. Kinetic studies in our laboratory (Melchior, 1965) have indicated that the monovalent ion exerts its effect through a direct interaction with the enzyme protein, while the divalent ion is involved in the formation of a complex ion with ADP. On the other hand, Mildvan and Cohn (1965) have been able to use the technique of nuclear magnetic resonance by substituting Mn^{++} for Mg^{++} and have shown that the divalent cation functions as a metal-enzyme complex. These workers further demonstrated that one divalent cation is bound per active site of the enzyme protein. More recent kinetic studies have tended to support this view and have suggested that free ADP rather than the Mg^{++} complex ion is the active species in the catalytic event. (Ainsworth and MacFarlane, 1975). It is apparent that two totally conflicting pieces of evidence about the role of the divalent ion have emerged.

It should be noted that Melchior and Melchior (1958) have shown the inherent difficulty of using kinetic data to determine the interactions in a system involving complex ions. Equilibrium measurements have been made using Mn^{++} as ligand, however several workers have reported that the properties of the enzyme in the presence of Mn^{++} differ significantly from those observed in the present of the physiological activator. (Suelter and Melander, 1963); Kayne and Price (1972) Leonard (1972).

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* The data presented in this paper was taken from the thesis submitted by Daniel Kamper to Roosevelt University in partial fulfillment of the requirements for the degree of Master of Science.

It is apparent that only equilibrium binding measurements can resolve these problems. Because of these considerations, we have employed gel filtration to measure the binding of Mg^{++} by pyruvate kinase.

METHODS

Rabbit muscle pyruvate kinase (PK) obtained from Calbiochem, was stored at 2°C as a suspension in 2 M ammonium sulfate. Before use, the crystals of enzyme were collected by centrifugation at 10,000 x g for 1 hour, followed by dialysis in the chamber described by Colowick and Wormack (1969) until free of ammonium ions. The enzyme concentration was determined by using the extinction coefficient of 0.52 at 278 mμ. The PK is a tetramer composed of four non-active monomers weighing approximately 60,000 daltons. For comparison, measurements were made of bovine serum albumin (BSA, 65,000 daltons) and β-lactoglobulin (βLG, 35,000 daltons). Both reference proteins were crystalline products, and the concentrations were calculated directly from the dry weights of protein.

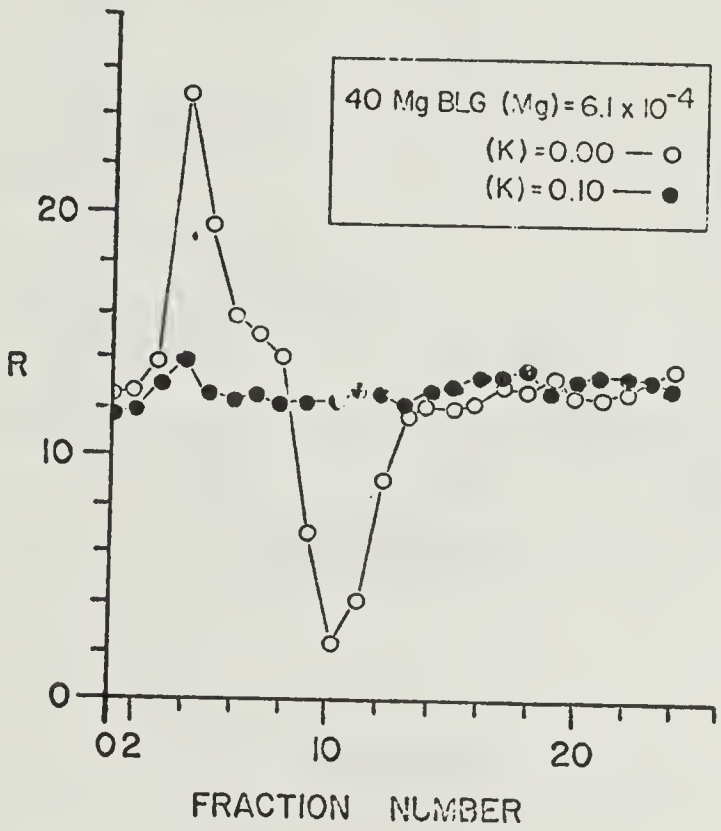
The columns used to measure the binding were filled with Sephadex (G-25-300) obtained from Sigma. The gel particles act as small spherical semipermeable membranes which allow the entrance of small molecules but exclude large ones; thus the protein-Mg^{++} complex moves rapidly through the column and is separated from its binding region. One ml sample of protein dissolved in a salt-buffer solvent was placed on top of the column which was equilibrated with the same solvent. Fractions were collected in preweighed disposable plastic tubes at a rate of 2.5 ml every 10 minutes. The tubes were recapped and reweighed to determine the exact volume of each fraction. Mg^{++} was determined on an aliquot of each fraction either by titration with ehtylenediamine tetraacetic acid using erichrome black-T as indicator or by use of a Perkin Elmer model 303 atomic absorption spectrophotometer.

The columns were 0.9 x 60 cm. and were water-jacketed. Temperature was maintained at 25°C. All solutions were kept at pH 7.0 by using a solution containing 0.01 M N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid (HEPES) and 2.5 mM tetraethylammonium or tetramethylammonium hydroxide.

Figure 1 illustrates a measurement of the binding of Mg^{++} by βLG; the protein-Mg^{++} complex moves through the column ahead of the "hole" which presents the amount of Mg^{++} removed by the protein.

FIGURE 1

BINDING OF MAGNESIUM BY β-LACTOGLOBULIN AS DETERMINED SEPHADEX GEL CHROMATOGRAPHY



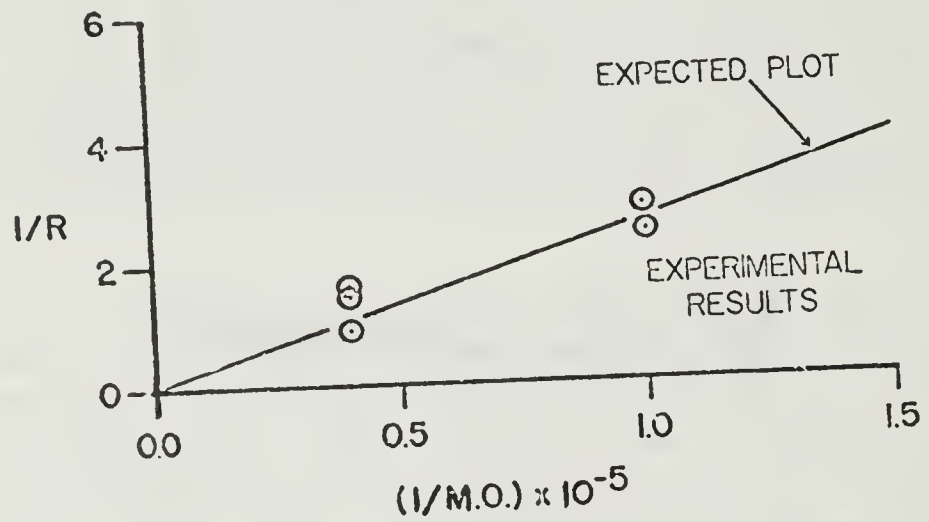
$$R = \frac{\text{Volume of Titrant}}{\text{Volume of Fraction}}$$

The binding data is presented in the form developed by Scatchard (1949). The reciprocal of R, which is defined as molecules of ligand bound per molecule of protein, is plotted against the reciprocal of the concentration of ligand. It has been shown that the slope of these graphs can be used to calculate the intrinsic binding constant, while the intercept is the reciprocal of the number of binding sites.

To verify the method, experiments were made on the binding of methyl orange by BSA at 7.5°C and compared to the classical equilibrium dialysis experiments of Klotz, et.al. (1946). Figure 2 shows the excellent agreement of the two methods.

FIGURE 2

BINDING OF METHYL ORANGE BY BSA



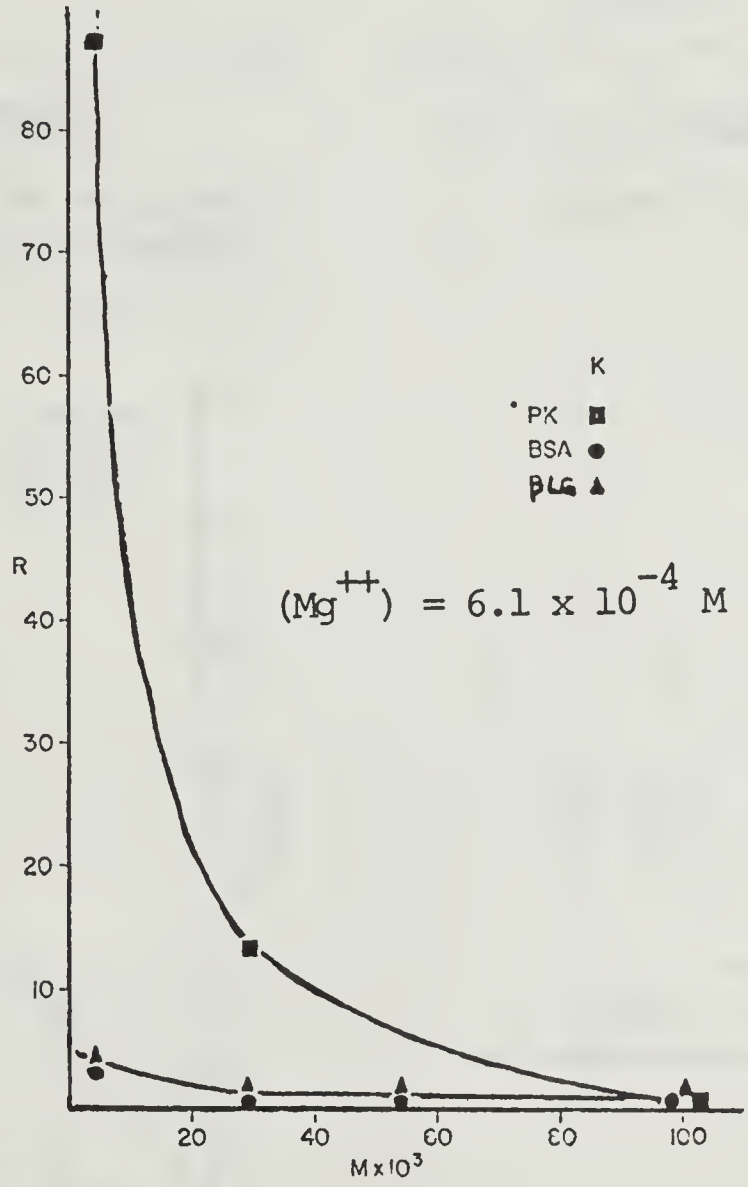
RESULTS

There are two major experimental problems in making equilibrium measurements of interactions of ions with pyruvate kinase. One is related to the stability of concentrated solutions; we have never achieved a solution of more than 3×10^{-5}M, which is equilivalent to 1.2×10^{-4}M active sites. This has necessitated making the studies of binding in extremely dilute solutions of ligand. The second problem is related to the fact that 0.1 M KCl is required for optimal activity of the enzyme; thus measurements of the completely active enzyme require high ionic strength.

The effect of ionic strength on the binding of Mg^{++} is illustrated in Figure 3. It is apparent that pyruvate kinase is particularly sensitive to changes in ionic strength: βLG and BSA show much smaller changes in binding as the salt concentration is increased.

FIGURE 3

BINDING OF Mg^{++} VERSUS IONIC STRENGTH



The sensitivity of binding to ionic strength coupled with the difficulty in achieving high concentrations of binding sites make estimation of binding of Mg^{++} by PK at its optimal catalytic activity impossible by any of the existing equilibrium methods. Measurements were made on the two reference proteins at low ionic strength and at 0.025 M; the results shown in Figures 4 and 5. It is apparent that the major effect of electrolytes is on the intrinsic binding constant rather than on the number of binding sites.

FIGURE 4

BINDING OF Mg^{++} BY BSA

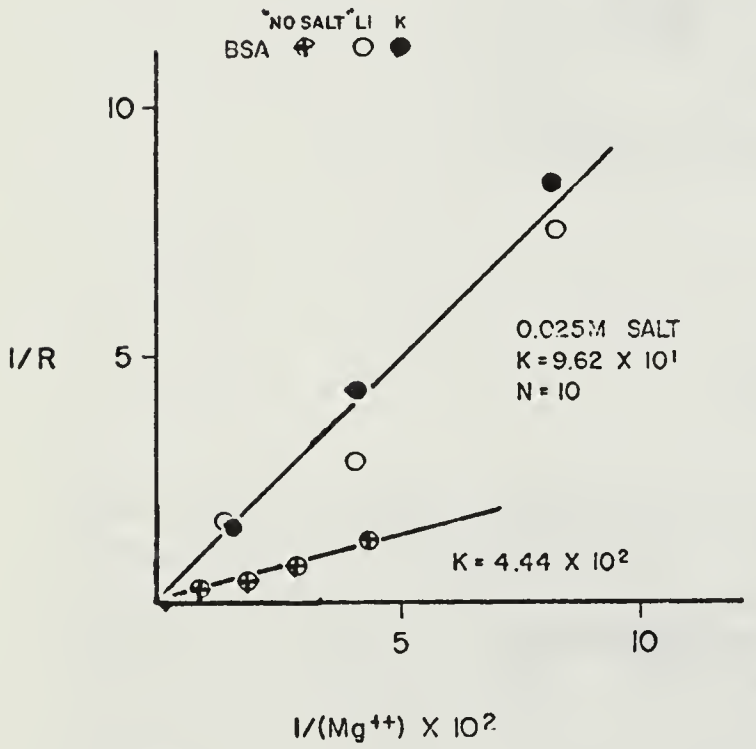
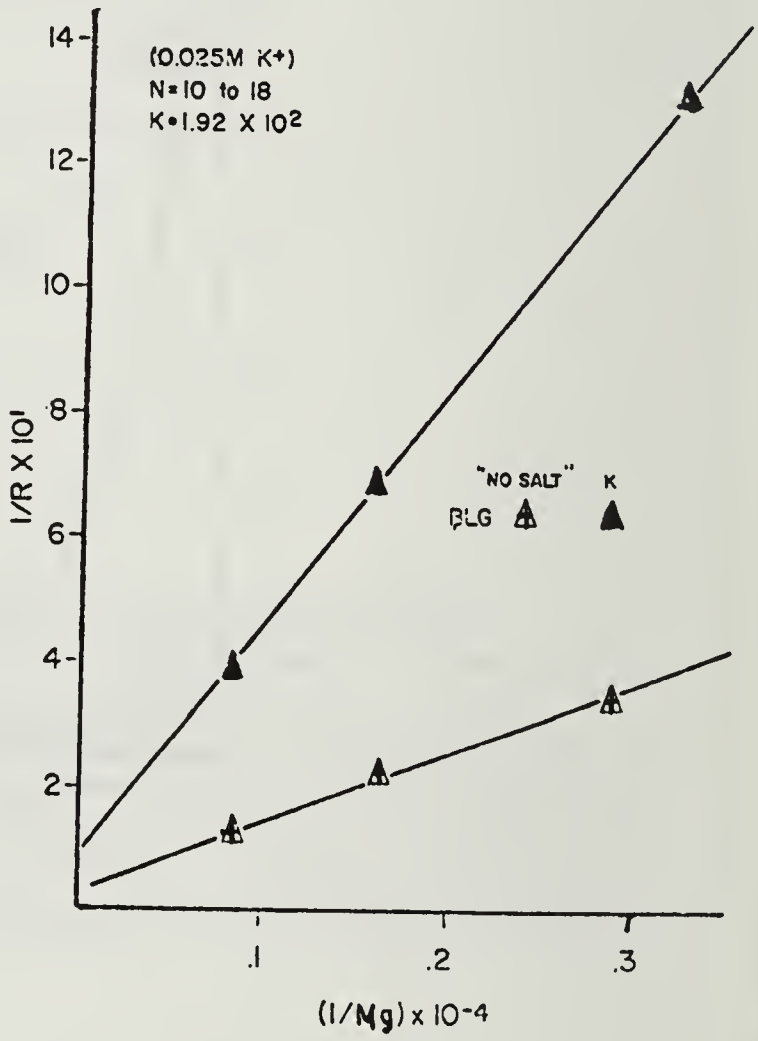


FIGURE 5

BINDING OF Mg^{++} BY βLG IN PRESENCE OF 0.025M K^{+}



The problems inherent in making measurements on PK are emphasized in Figure 6. In the absence of background electrolyte, the inhibition of binding at high ionic strength produces an apparent maximum in the binding curve. Attempts to gather data at 0.025 M salt solution produced a wide scatter of results which made calculation of the usual constants meaningless. However, it was noted that no difference in the effects of Li^+ and K^+ could be observed.

FIGURE 6

BINDING OF Mg^{++} BY PYRUVATE KINASE

R VERSUS (Mg^{++})

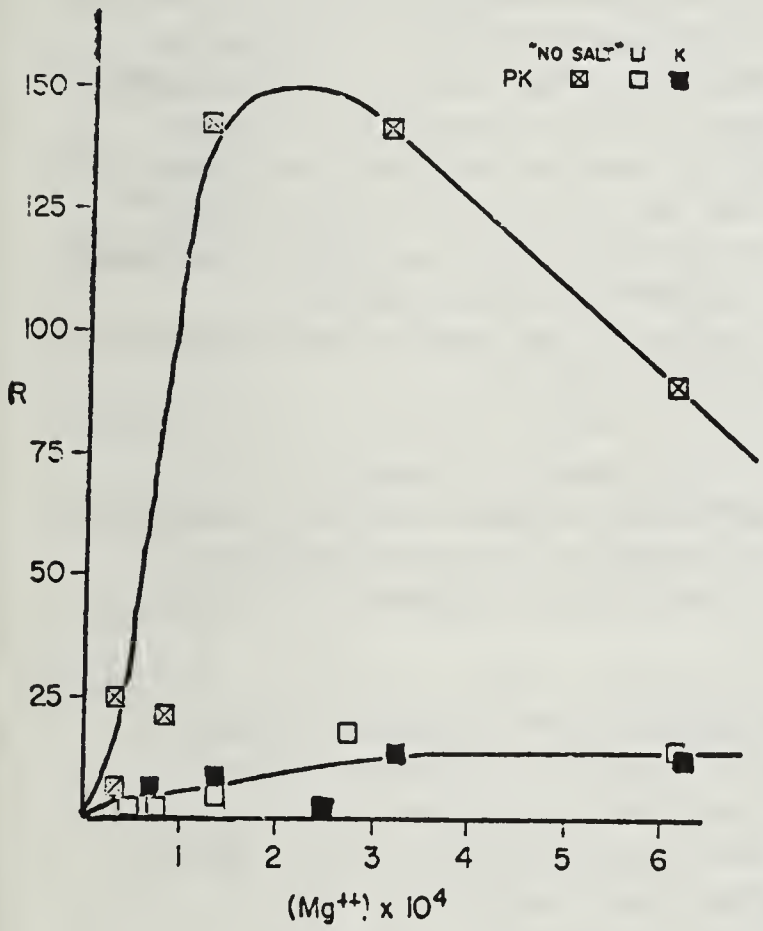
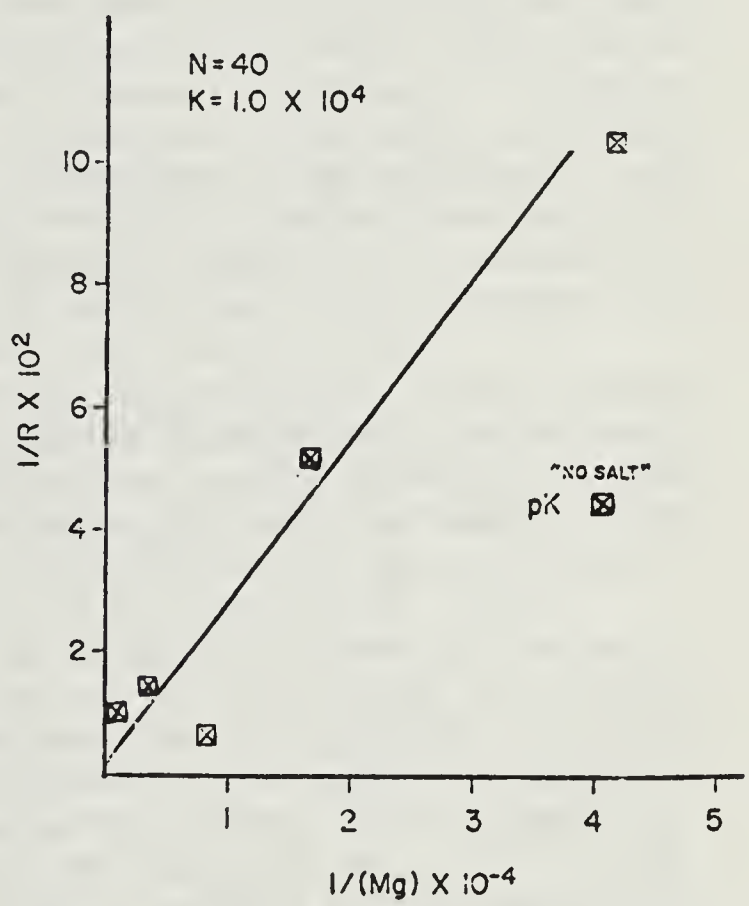


FIGURE 7

BINDING OF Mg^{++} BY PYRUVATE KINASE

NO K^+ OR Li^+ PRESENT



A Scatchard plot of the data collected the lowest ionic strength is shown in Figure 7. PK appears to bind approximately 40 Mg^{++} with an intrinsic binding constant of about 1 x 10^4 liters per mole.

DISCUSSION

It is apparent that equilibrium binding measurements are required to establish the exact role of the metal ion activators in the pyruvate kinase reaction. However, the high ionic strength required for optimal activity of the enzyme coupled with the instability of concentrated solutions of the enzyme preclude obtaining valid results by any of the known techniques. At low ionic strengths, PK binds Mg^{++} strongly, showing an intrinsic binding constant that is approximately 20 fold greater than that observed with BSA or βLG.

The data presented on the binding of Mg^{++} by BSA and βLG indicated that the effect of ionic strength is to alter the apparent intrinsic binding constant, not the number of binding sites. The effects of ionic strength on the activity of a protein are complex and difficult to predict (Tanford, 1967). From the results presented here, it appears that increasing the salt concentration lowers the activity coefficients of the free ligand or the protein more than that of the Mg^{++} protein complex. Assuming the same situations holds for PK, we can conclude that even when fully activated, PK can bind up to 40 molecules of Mg^{++} per mole of enzyme, or about 10 per active site. This is quite different from the conclusion of Mildvan and Cohn (1965) who employed Mn^{++} to demonstrate that one divalent cation is bound per active site when the enzyme is fully activated by the monovalent cation.

These results emphasize the great caution that must be used in translating kinetic studies into conclusions about equilibrium binding. Because pyruvate kinase is specifically affected by both monovalent and divalent cations, it is impossible to study the effects of ionic strength *per se* on its catalytic potency.

A number of previous attempts to find an effect of K^+ on the enzyme that is not duplicated by the non-activating ion Li^+ have met with failure. Techniques that have been used include circular dichromism (Wildes, et. al., 1971), binding of ADP and Phosphoenolpyruvate (Betts and Evans, 1968), sovent perterbation techniques (Melchior, et. al., 1969, 1970). To this list we can now add the apparent lack of any difference in the binding of Mg^{++} when 0.025 M Li^+ is substituted for 0.025 M K^+.

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